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BLACKEYE BEANS IN CALIFORNIA

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BLACKEYE BEANS IN CALIFORNIA[1]

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WHAT IS THE BLACKEYE, a bean or a pea? In the southern states, where it is contrasted with the garden, or English, pea, it is called a pea. In general over the United States it is known as a cowpea, but in California it is known only as the Blackeye bean (Wells, 1941).[3] In the South, where it is more generally cultivated than elsewhere, it is used both as a green pea in the garden and as a field crop. The seed is used as a popular food for human consumption, and the forage is either used as pasture and feed for stock, or it is plowed under to enrich the soil. In California the crop is grown almost exclusively as a dry bean, cultivated and harvested like other bean crops of the state. For this reason it is classified under the tariff as a bean (U. S. Tariff Commission, 1920). The large acreage of Blackeyes in California (estimated ten-year average of over 50,000 acres producing 792,000 one hundred-pound sacks in 1944)[4] is grown mainly for shipment to the markets of the southern states where the bean is used as food and as seed.

HISTORY AND ORIGIN OF THE BLACKEYE BEAN

Botanically the Blackeye is neither a pea nor a bean but is a member of a distinct genus of the pea family, distinguished by its value as a food and as a forage plant. Undoubtedly it originated in central Africa, in which region only are the wild plants or species found (Piper, 1913). From central Africa the plant spread through Egypt to Asia and to the Mediterranean region where it was well established in remote times. To the species *Vigna sinensis* is given the name cowpea, a species that includes the varieties now extensively under cultivation. Two other cultivated species, *V. Catjang,* or catjang cowpea, and *V. sesquipedalis,* the asparagus, or yard-long, bean, differ from ordinary cowpeas in the shape and length of their pods as well as in their usually smaller seeds. Abundant evidence exists that all three species should be classified as one (*V. sinensis*) because all of them cross readily. The same is true for their wild progenitors. Other species of this group of legumes, notably *V. lutea,* appear to be true species which the writer has not been able to cross after many years of trials. The haploid chromosome number for all species of the genus is 12 (Senn, 1938).

That the cowpea has been under cultivation for centuries is evidenced by its widespread culture in ancient times in Africa, Asia Minor, India, China, and in the Mediterranean region, where it was described by the earliest Roman writers. It is still grown in Italy where the Blackeye is known by the same name as the kidney bean (*Phaseolus vulgaris*) from America which largely supplanted it. The Blackeye was probably introduced into the American colonies, for Sloane—a pre-Linnaean botanist—describes the bean there in

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[3] See "Literature Cited" for complete data on citations, referred to in the text by name of author and date of publication.

[4] Westan Bean News. 2 p. Published by The Westan Bean Growers Association, Wesley, California. August 19, 1944. (Processed.)

1707 (Wight, 1907). Later importation undoubtedly arrived with slaves from Africa. Introduction of the Blackeye into Virginia was made by General Washington, and the use of the name cowpea is ascribed to Thomas Jefferson, who believed the bean was a native of America, because it was extensively used by the Indians (Carrier, 1923).

SPREAD OF COWPEAS IN THE UNITED STATES

From the recorded beginning in 1707, the cowpea in 1919 covered 1,500,000 acres producing 750,000 tons of hay and 3,000,000 bushels of seed (Piper, 1924). By 1940 some 5,020,000 acres were grown in the United States (California excluded); of these, 1,385,000 acres produced 8,712,000 bushels of seed, or 6.3 bushels per acre. In addition, on an estimated 67,240 acres California produced 1,923,333 bushels of Blackeyes, or 11.5 bushels per acre.

TABLE 1

ACREAGE AND YIELD PER ACRE OF COWPEAS* FOR SEED BY STATES, AVERAGE 1929 THROUGH 1938

State	Acreage harvested	Yield per acre
	acres	*bushels*
North Carolina	48,000	7.7
South Carolina	174,000	5.7
Georgia	143,000	5.9
Florida	10,000	8.8
Tennessee	32,000	5.4
Alabama	161,000	5.7
Mississippi	108,000	5.8
Arkansas	83,000	6.9
Louisiana	40,000	8.5
Oklahoma	26,000	5.5
Texas	133,000	7.0
California (Blackeyes)	52,400†	20.0†

* United States Department of Agriculture. Agriculture Statistics 1941:307. 1941.
† Estimated.

The production of Blackeye beans in California is attributable entirely to the sale of the greater part of the crop for human consumption to the southern states, and with limited quantities to Puerto Rico and Cuba. This competition with the southern states is possible because of the higher yields obtained in California (11.5 bushels per acre as compared with 6.3 bushels in the South) and because of the excellent quality produced by the practically rainless summers that favor brightness of seed.

In contrast to the California-grown Blackeyes, the cowpeas grown for seed in the southern states are not classed as beans (Morse, 1920*b*). There, because of the small area plantings and the rainy summers that cause poor quality and severe weevil attacks, the market for cowpeas does not compare favorably with that of the California Blackeye (U. S. Dept. Agr. Yearbook of Agriculture, 1941). The cowpea is recognized, however, as the most important legume grown in the southern states where it is extensively used for green manuring and for stock feed. The 1,385,000 acres of cowpeas grown and harvested for seed in the southern states (Barr, 1923) yielded an average of 6.3 bushels per acre valued

at $1.38 a bushel, or a total value of $12,040,000. The crop of cowpeas harvested for seed occupied 27.5 per cent of the 1940 acreage and was distributed as follows: used for seed, 32 per cent; fed to livestock, 20 per cent; used on farm, 8 per cent; and sold, 40 per cent. In contrast, the California-grown Blackeye is sold as a dry bean and shipped to the southern states mainly for human con-

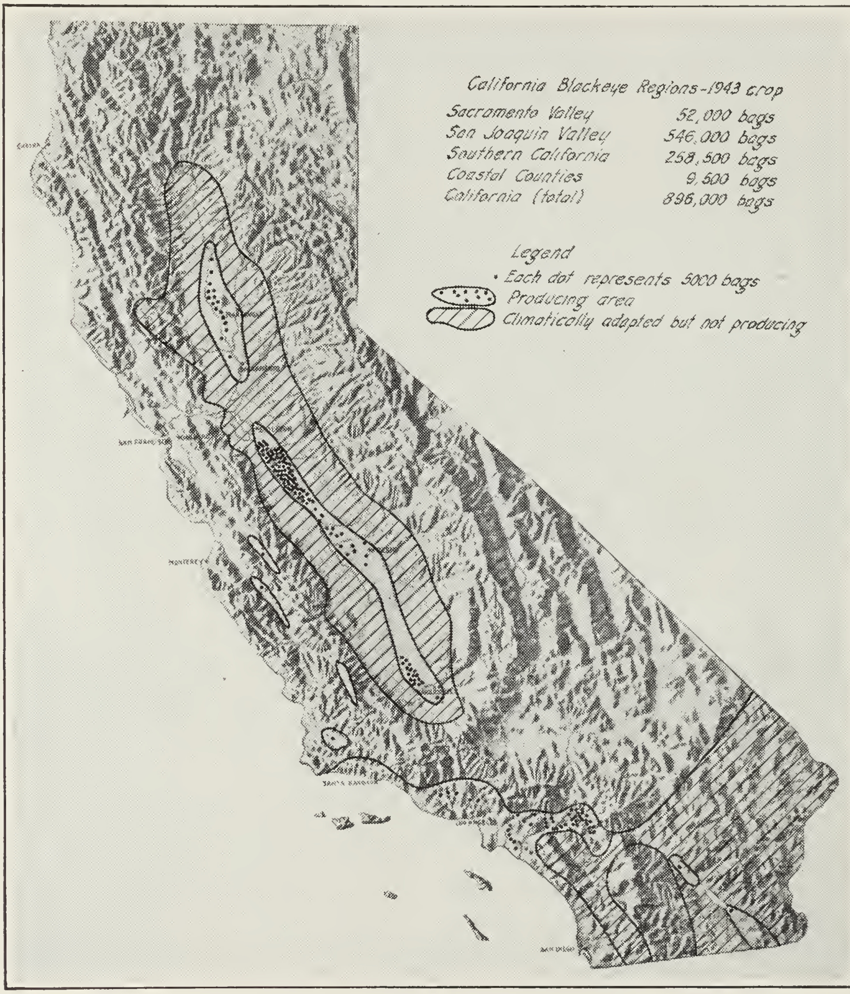

Fig. 1.—Blackeye-bean-producing areas and other areas climatically adapted to Blackeye beans.

sumption. It has been sold at an average price, for the past ten years, of $2.49 a bushel as contrasted with $1.38 a bushel for southern-grown cowpeas—a price difference of 80.4 per cent in favor of California Blackeyes. This price differential is due largely to the absence of rain during the crop season in California, a condition which insures a high quality in the bean and places the California Blackeye, by the market, in a class by itself.

The average acreage and yield of cowpeas for seed in the United States for 1929 through 1938 are given in table 1.

The culture of the Blackeye bean began fairly late in California, the earliest market reports appearing in 1880 (Hendry, 1921). From this date until the Blackeye appeared in the bean-market reports in 1909 there apparently are no authentic records. At this time the crop was centered in Stanislaus County. Bean reports from San Francisco (Wickson, 1910, p. 191) in 1909, segregate production in 80-pound bags as follows: Sacramento Valley, 40,000; San Joaquin Valley, 78,000; central coast, 22,000; and southwest coast, 50,000, making a total of 190,000 bags. Since 1909, the total production has increased about four times in thirty-three years, or 733,000 bags from an estimated 61,000 acres in 1942. The annual values at the same time increased about twelve times—from $364,000 to $4,251,000. The distribution of production from 1931 to 1943 is given in table 10.

Since the distribution in production has not varied materially in the past, the average percentages from 1929 to 1942 inclusive may be taken as reliable for the areas as follows: southern California, 37.0; coastal counties, 0.12; San Joaquin Valley, 55.0; Sacramento Valley, 7.4. During 1943 marked increase in acreage in Kern (8,000 acres), Tulare, Kings, Fresno, and Madera counties may shift the center of production southward in the San Joaquin Valley. This trend is emphasized by the resistance of the Blackeye to heat, which is harmful to the setting of seed of common beans in this area. New varieties resistant to nematodes, which are well established in old vineyards and in alfalfa and cotton fields, give added impetus to Blackeye production in these counties. The map (fig. 1) shows this distribution of Blackeye production by areas.

CLIMATIC CONDITIONS GOVERNING BLACKEYE PRODUCTION

The cowpea, of which the California Blackeye is a variety, originated in the tropics of central Africa and is therefore tolerant of heat but adversely affected by low temperatures. The map (fig. 1) showing the areas producing Blackeye beans clearly indicates climatic preferences. The temperature limitations are given in table 2.

The area adapted to Blackeyes as outlined by temperature limitations (table 2) was first determined by the effect on Blackeye crops by actual tests. When Blackeyes and cowpeas are grown under low temperatures, adverse effects upon the growth of the leaves and the vines, and upon the production of fruit are observed. In the San Francisco Bay area, Blackeyes cannot be profitably produced. The seed germinates and the plants grow, but growth is delayed and the plants are small. The leaves are cupped and wrinkled or are embossed, in appearance similar to the leaves of sugar beets affected by curly top. This condition in fields of Blackeyes was observed east of King City in the Salinas Valley and in several coast areas, including Oxnard, Santa Barbara, Santa Cruz, and other localities under influence of the cold summer fogs. The leaves also show purplish coloration and the stems are definitely purpled. The purplish color is frequently associated with the effect of powdery mildew which is favored by the cold fogs.

The fruiting is affected more adversely than are the vegetative parts. Under the coldest conditions, such as prevail at Berkeley, the flowers set, but few pods develop and these drop off before seeds are set. No pods mature normal seeds.

TABLE 2

Relation of Temperatures* in California Blackeye Areas to the Glowing and Harvesting Season

Area	Elevation	Years observed	April				May				June				July			
			Maximum	Minimum	Mean	Departure†	Maximum	Minimum	Mean	Departure†	Maximum	Minimum	Mean	Departure†	Maximum	Minimum	Mean	Departure†
	feet	*number*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*
Chico	189	73	84	32	58.6	−1.6	101	35	65.4	−1.5	101	43	68.0	−7.2	107	54	77.6	−3.6
Davis	51	71	83	34	58.6	−0.9	100	38	67.2	+1.3	104	41	67.8	−4.9	108	49	75.8	−0.4
Stockton	20	72	83	34	57.4	−1.8	97	38	64.0	−0.9	103	42	65.8	−5.3	104	47	72.2	−2.9
Modesto	90	72	81	38	59.0	−0.2	98	40	66.3	+0.7	103	45	67.0	−4.6	103	52	74.8	−1.1
Fresno	277	61	87	41	62.1	+1.9	103	43	70.4	+3.2	105	50	71.6	−4.1	107	56	81.0	−0.3
Bakersfield	489	54	88	42	62.2	−0.6	103	41	78.0	+0.8	106	44	72.4	−5.3	110	57	82.2	−1.9
Riverside	895	62	91	36	60.8	+0.5	98	40	66.0	+1.5	101	47	68.4	−1.7	110	48	74.4	−1.4
Imperial	−65	23	100	45	72.1	+1.4	106	55	79.1	+1.1	110	53	82.2	−3.1	119	62	89.9	−1.9
Berkeley	299	56	70	44	56.6	+1.3	89	44	57.8	+2.2	88	48	58.6	−0.2	81	51	61.0	−0.3
King City	331	56	—‡	—	—	—	—	—	—	—	101	40	64.5	−1.6	97	45	67.4	−1.2
Oxnard	51	19	77	41	57.8	+0.6	86	38	59.5	+0.4	82	43	60.0	−1.2	76	46	63.0	−1.5
Santa Ana	133	33	89	38	60.2	+0.1	97	41	65.0	+1.5	93	43	65.8	−1.5	101	48	70.6	−0.9

Area	Elevation	Years observed	August				September				October			
			Maximum	Minimum	Mean	Departure†	Maximum	Minimum	Mean	Departure†	Maximum	Minimum	Mean	Departure†
	feet	*number*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*
Chico	189	73	105	48	73.4	−5.8	109	48	74.6	+1.7	99	30	61.8	−2.1
Davis	51	71	101	46	72.0	−3.0	104	46	72.3	+1.6	97	39	61.7	−1.9
Stockton	20	72	98	47	70.5	−3.1	101	46	72.2	+0.9	96	36	61.4	−1.3
Modesto	90	72	97	49	71.6	−2.7	100	50	71.6	+2.1	93	40	61.6	−0.9
Fresno	277	61	102	54	72.2	−2.3	103	54	75.8	+3.8	97	38	64.4	+2.1
Bakersfield	489	54	104	55	79.0	−3.0	—‡	—	—	—	100	40	66.6	+1.1
Riverside	895	62	101	49	75.2	−0.7	113	49	75.2	+5.0	104	41	69.0	+4.1
Imperial	−65	23	110	67	88.8	−2.4	113	64	87.8	+3.7	105	45	74.8	+1.1
Berkeley	299	56	82	53	61.8	+0.6	95	53	64.2	+2.0	81	45	61.2	+1.0
King City	331	56	96	40	65.0	−3.2	108	40	68.4	+1.7	102	30	60.4	−2.0
Oxnard	51	19	76	46	63.0	−1.5	96	45	63.4	−0.2	81	40	64.0	−1.2
Santa Ana	133	33	93	51	72.4	+0.5	102	44	72.9	+3.5	95	40	65.4	+0.8

* Norquest, C. E. Climatological Data—California Section, 1943. p. 146–47, 151. U. S. Weather Bureau, San Francisco, California.
† Departure means variation (±) from normal.
‡ Dashes indicate data not available.

Such seeds as are matured are shriveled, badly wrinkled and discolored, and are wholly unmarketable. The area where these conditions prevail is found in the entire north-coast region including the San Francisco Bay area inland to the mouth of the San Joaquin River and all the south-coast region down to Point Concepcion. In the area marked no. 2 (fig. 1) there are valleys back from the coast, protected by mountain ranges, that are well adapted to the growing of Blackeyes. One such valley is found in San Benito County from Hollister to Bitterwater.

In the Santa Ynez Valley, Blackeyes can be produced successfully on summer-fallow nonirrigated land. Below Point Concepcion the protection of the Channel Islands moderates the summer temperatures and permits the growing of Blackeyes closer to the ocean. In Ventura County, Blackeyes are grown successfully in the Ojai Valley and at Camarillo; they are also grown eastward and in the inland valleys east of the Malibu Mountains, in San Fernando Valley, and in similar valleys in Los Angeles County. In the hilly areas of Orange County and in similar areas in San Diego County not far from the coast, Blackeyes thrive, especially in those areas too far from the ocean to be favorable for lima beans.

High temperatures, in contrast to low temperatures, do not in any way adversely affect Blackeyes except in the Imperial and Coachella valleys of California (Cosby and Goar, 1934). In these areas when Blackeyes are planted in the spring, with the fruiting period occurring in the intense heat of July and August, many blossoms and young pods drop off through premature abscission caused by the heat. The beans also may be misshapen, discolored, lacking in normal wrinkling, and badly affected by aphid spot. Late planting in July and August escapes heat damage more than spring planting; nevertheless, heat damage is a grave drawback and may seriously damage the yield and quality of the crop. In Riverside and San Bernardino counties, nearest to the desert regions, no heat damage is encountered.

RAINFALL IN BLACKEYE AREAS

Rainfall (table 3) has no beneficial influence on Blackeye production in California except to store winter moisture in the soil and subsoil for the bean crop planted after the rainy season has passed. This condition is especially true for those coastal areas without irrigation where beans are grown on fallowed land. In the San Joaquin Valley, where rainfall is low, Blackeyes have not made profitable crops on fallowed, unirrigated land, but in the Sacramento Valley, where the rainfall is heavier and the soils more retentive of moisture, successful crops of Blackeyes have been grown without irrigation. These areas are limited to the better and softer soil types.

Rainfall may cause considerable damage to a Blackeye crop by falling on fields where the beans have been planted but have not yet emerged from the soil. The crust formed by the rain causes many of the seedlings to turn back. Where the seedlings are in this condition, soil fungi may destroy many of them. Harrowing is sometimes used to break the crust, but by this method so many seedlings are destroyed or injured that many farmers prefer to cultivate the ground and to replant.

The greatest damage to the Blackeye crop by rains occurs at harvest time.

In those fields planted in June and July early fall rains may find the crop uncut, in the windrow, or in the process of being threshed. Not only is the expense of threshing greatly increased by the delay and by the turning of bean windrows and shocks for drying before threshing, but also many softened beans are injured by the thresher and must be hand-picked if not removed in the reclean-

TABLE 3

Rainfall* during the Growing and Harvesting Season in California Blackeye Areas

Area	Elevation	Years observed	April		May		June		July	
			Actual	Departure†	Actual	Departure	Actual	Departure	Actual	Departure
	feet	*number*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
Chico	189	73	3.25	+1.76	0.42	−0.59	0.31	−0.14	Trace	−0.03
Davis	51	71	1.44	+0.55	0.25	−0.29	0.06	−0.08	0.00	0.00
Stockton	20	72	1.74	+0.33	0.00	−0.62	0.03	−0.09	0.00	−0.01
Modesto	90	72	1.27	+0.51	0.00	−0.17	Trace	−0.17	0.00	0.00
Fresno	277	61	0.09	−0.05	0.00	−0.44	Trace	−0.08	0.00	−0.01
Bakersfield	489	54	2.39	+1.81	0.25	−0.21	0.00	−0.06	Trace	−0.01
Riverside	895	62	1.57	+0.68	0.00	−0.50	0.40	0.00	0.00	−0.08
Imperial	−65	23	Trace	−0.18	0.00	−0.05	0.00	−0.02	0.00	−0.14
Berkeley	299	56	2.03	+0.85	0.05	−0.85	0.03	−0.17	Trace	−0.01
King City	331	56	——‡	——	——	——	0.00	−0.06	0.00	0.00
Santa Ana	133	33	0.95	+0.06	Trace	−0.51	Trace	−0.06	0.00	0.00
Oxnard	51	19	0.86	−0.23	0.07	−0.17	0.00	−0.09	0.00	−0.05

Area	Elevation	Years observed	August		September		October		Average April–October	
			Actual	Departure†	Actual	Departure	Actual	Departure	Total	Departure
	feet	*number*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
Chico	189	73	0.00	−0.01	0.00	−0.59	0.34	−0.70	4.32	−0.30
Davis	51	71	0.00	−0.01	0.00	−0.33	0.21	−0.46	4.19	+0.23
Stockton	20	72	0.00	−0.01	0.00	−0.31	0.19	−0.43	1.96	−1.14
Modesto	90	72	0.00	−0.03	0.00	−0.15	0.33	−0.13	1.60	−0.14
Fresno	277	61	0.00	−0.01	0.00	−0.21	0.06	−0.51	0.96	−1.31
Bakersfield	489	54	0.00	−0.01	——‡	——	0.50	−0.24	2.64	+1.42
Riverside	895	62	0.00	−0.12	0.00	−0.21	0.36	−0.27	1.61	−0.19
Imperial	−65	23	0.90	+0.53	0.38	+0.05	0.00	−0.21	1.28	+0.19
Berkeley	299	56	0.00	−0.03	0.01	−0.48	0.74	−0.36	2.86	+1.05
King City	331	56	0.00	0.00	0.00	−0.18	0.22	−0.10	——	——
Santa Ana	133	33	0.00	−0.02	0.00	−0.21	0.24	−0.40	1.19	−1.14
Oxnard	51	19	0.00	−0.05	0.00	−0.15	0.53	−0.05	1.46	−0.79

* Norquest, C. E. Climatological Data—California Section, 1943. p. 146–47, 151. Weather Bureau, San Francisco, California.
† Departure means variation (±) from normal.
‡ Dashes indicate data not available.

ing. The discoloration of beans from fall rains may cause a considerable discount in the sale price and in the demand. In years of considerable rain damage, injured stocks are held over as low grade without ready sale. Where double cropping (beans planted in June or July after grain or other winter crop) is practiced, the risk of rain damage is greatly increased. By referring to table 3 the periods when fall rains may be expected can be determined within practical limits for the various Blackeye areas.

Table 3 indicates that rains may be expected in the month of May, especially

in northern areas. If planting after May 15 is practiced, little or no spring damage occurs. Planting about May 20 is ideal for best yields and quality. Early planting usually avoids damage from fall rain. Blackeyes planted early on summer-fallowed, unirrigated lands are harvested in late August and in the first 2 weeks of September. On irrigated land the harvest is somewhat later, but should be completed between September 15 and September 20 before more than a trace of rain occurs. In the regions from Stockton southward, Blackeyes harvested by these dates usually escape rain damage. Late-planted beans may not be harvested until after the middle of October when winter rains may be expected.

TABLE 4

Estimates of Production of California Blackeye Beans* by Districts, 1929 Through 1943†

Year	Southern California	Coastal counties	San Joaquin Valley	Sacramento Valley	Total for state
	100-pound bags	*100-pound bags*	*100-pound bags*	*100-pound bags*	*100-pound bags*
1929	151,100	—‡	340,500	22,400	514,000
1930	269,000	—	536,000	47,000	852,000
1931	160,300	500	278,600	19,600	459,000
1932	96,300	400	157,600	20,700	275,000
1933	184,200	200	375,500	27,100	587,000
1934	173,100	600	326,400	24,900	525,000
1935	182,100	1,200	392,300	39,400	615,000
1936	228,400	500	400,000	76,100	705,000
1937	393,400	800	409,800	53,000	857,000
1938	246,800	2,000	232,900	30,300	512,000
1939	263,000	4,300	277,000	28,700	573,000
1940	430,200	13,000	636,800	74,000	1,154,000
1941	246,700	5,700	414,500	37,100	704,000
1942	271,600	9,000	402,000	50,400	733,000
1943	258,500	9,500	546,000	82,000	896,000

* California Crop and Livestock Reporting Service, Sacramento, California.
† [Clarke, L. M.] Bean production by varieties for California and other leading states. p. 2. California Crop and Livestock Rept. Serv. 1944. (Mimeo.)
‡ Dashes indicate data not available.

FROSTS AND WINDS

Frost damage does not occur for two reasons: because Blackeyes in all areas are planted after the danger of frost is past; and because in the fall the early frosts actually hasten maturity, without material damage, except to very late plantings and to crops used for forage.

Severe north winds sometimes cause losses after the beans are windrowed or shocked. The rolling of windrows and the tumbling of piled vines thresh out beans and may even blow the rolling piles from the field. This type of wind injury is more likely to occur in the Sacramento and northern San Joaquin valleys than in other parts of the state. When threshing is done immediately after windrowing, wind losses are usually avoided.

DISTRIBUTION OF BLACKEYE-BEAN CULTURE

The recording of the distribution of Blackeye-bean culture by counties does not appear feasible. The more natural method of dividing the state into areas according to climate and irrigation initiated by Wickson (Hendry, 1921) has been followed in table 4.

During the years from 1929 through 1932 little change in production occurred except variations in supply and demand, but for the years 1940 through 1943 production varied widely with marked increase. The proportionate distribution of Blackeye-bean culture by areas is shown in table 5.

The increased production of Blackeye beans in California is centered in northern San Joaquin Valley where the industry first became established. The Blackeye is favored in this area by the Manteca, Modesto, Turlock, and Merced irrigation districts which afford abundant and certain supplies of water during the growing season. In southern California, production follows that of the San Joaquin Valley; this is attributable to a number of factors, such as the ability of the Blackeye to grow beyond the foggy coastal limits of the lima bean, its resistance to heat, and its ability to produce crops without irrigation in the coastal valleys. The Sacramento Valley has made a high percentage increase but a limited actual increase in production mainly because of restricted soil conditions, especially in the available sandy soils preferred by the Blackeye. The coastal counties show a rapid percentage increase in appreciation of the ability of the Blackeye to grow in nonirrigated valleys away from the fog belt of the coast.

TABLE 5

DISTRIBUTION OF BLACKEYE PRODUCTION FOR 1929 THROUGH 1932 AS COMPARED WITH 1939 THROUGH 1943*

Region	1929 through 1932 total	1940 through 1943 total	Increase	Percentage of state 1940–1943
	100-pound bags	*100-pound bags*	*per cent*	*per cent*
Southern California	676,700	1,207,000	78.3	34.6
Coastal counties	900	37,200	403.3	1.1
San Joaquin Valley	1,312,700	1,999,300	52.3	57.3
Sacramento Valley	109,700	243,500	122.2	7.0
State	2,100,000	3,487,000	66.0	100.0

* Data calculated from table 4.

San Joaquin Valley.—The character of the soil and the availability of irrigation water sharply define the areas suitable to Blackeye production in the San Joaquin Valley. The climate everywhere is favorable. The water available for irrigation is divided into two sources: (1) gravity water from streams from the Sierra Nevada and (2) water pumped from wells. Both systems are subject to local variations which are described under "Irrigation" (p. 16).

Blackeye beans prefer sandy soils, a tendency that has been responsible for their spread in the sandy soils on the east side of the San Joaquin Valley. The San Joaquin River and the trough of the valley sharply divide the areas best adapted to the bean. The heavy soils of the valley trough and of the west side have not been found satisfactory for profitable Blackeye production. Here, the Blackeyes produce an abundant growth of vines on heavy soils even superior in places to the sandy east-side soils, but the setting of fruit and the quality of the seed are usually inferior. "Aphid spot" is very frequent in fields on the west side. The cutting of the vines is also more difficult. The heavy soil adheres to the roots and is carried into the thresher where, in the seed, it leaves a consider-

able amount of soil particles so nearly the same shape, weight, and size of the beans that they cannot be completely separated by machinery and must be removed by the expensive method of hand picking. These conditions are absent in the sandy Blackeye fields of the east side. The west-side soils favor the production of baby limas, Pintos, and mung beans.

On the east side the Blackeye production is confined to the sandy and soft loamy soils. Adobe soils should be avoided for Blackeye production, except where special varietal tests have proved adaptable. Red soils with shallow hardpan produce poor yields; indeed, red color in soils is frequently associated with low yield. The best soils for Blackeyes are found south of the black-adobe soils near Stockton, west of the red soils adjacent to the foothills of the Sierra Nevada, east of the valley trough, and toward the southern part of Kern County as far as irrigation is available. Within this area are found alkali soils, hog wallows, and soils not adapted to irrigation that must be excluded.

The peat and muck soils of the San Joaquin Delta have produced crops of Blackeye beans, but the high water table usual in this area interferes with root penetration and may cause rotting of roots. For these reasons and the correlated attacks of stem canker (sore shin) caused by *Rhizoctonia solani*, Blackeye culture has been discouraged in the San Joaquin Delta. In contrast to the difficulties of growing Blackeyes on the flat, poorly drained soils of the Delta, these beans have produced well when grown on the levees protecting the Delta islands. The cultivation of the levees for the Blackeyes destroys weeds and breaks up the large cracks which appear during the dry season. No irrigation is needed for this type of culture.

Sacramento Valley.—Production of Blackeye beans in the Sacramento Valley may always be limited by the preponderance of heavy soils unfavorable for the best yields. Sandy soils common in the San Joaquin Valley do not occur in the Sacramento Valley, but loamy, silty soils of the river bottoms of the Sacramento River and its tributaries, as well as of adjacent areas, produce good crops of Blackeyes. As in the San Joaquin Valley, the red soils, especially those underlain with red hardpan, have been found unsuitable. The black-adobe soils producing rice have shown promising adaptation, especially to the vigorous variety Blackeye 7711. Specific cultural adaptations for growing Blackeyes on black-adobe soils are needed to secure a satisfactory seed bed that will maintain moisture until the Blackeye roots reach the abundant underlying moisture. Preirrigation is desirable but irrigation after planting is not needed and would cause excessive weed growth.

Although irrigation is necessary on most of the soils devoted to Blackeyes in the Sacramento Valley for best yields, it is not necessary on many of the loamy, moisture-retaining soils. On such soils, usually occupied by grain crops, Blackeyes can be grown on summer-fallowed land which can again be planted to grain in the fall after the Blackeye crop has been harvested.

Southern California.—In southern California, south of a line running eastward from Point Concepcion across the Tehachapi Pass to the Colorado River, is an area that ranks next to the San Joaquin Valley in production of Blackeye beans. In the coastal region the Blackeye cannot compete profitably with the large lima bean, but does successfully occupy the areas eastward of the fog belt where lima beans are not well adapted because of the heat and aridity.

This area extends eastward, including San Bernardino and Riverside counties and many intermountain valleys southward to the Mexican border.

In the desert regions of the Coachella and Imperial valleys, Blackeyes have encountered difficulties because of high temperatures. Early plantings in February and March, or late plantings in July and August avoid much of the unfavorable temperatures. These very early and very late plantings favor the harvesting of green pods for the early and late markets in the cities of southern California. The crop of dried Blackeyes is usually light and is frequently injured in quality by aphid spot. The favorable effect of the Blackeye crop in these valleys upon soil fertility is shown in the crops that follow, whether harvested as seed or plowed under.

Coastal Counties.—The coastal region north of Point Concepcion in Santa Barbara County is the least important of the Blackeye divisions because of cold summer fogs. In the Salinas Valley the Blackeye cannot be grown profitably north of King City. This region, however, is well adapted to Pink and Small White beans. To the east of King City, protected by the inner Coast Range, lie small valleys where Blackeyes are well adapted either on irrigated or summer-fallowed land. Other similarly protected inland valleys southward to Point Concepcion are adapted to Blackeyes.

CULTURE

The plowing and preparation of the soil for the planting of Blackeye beans depend upon the preceding crop. If the preceding crop was Blackeyes, the soil is left undisturbed throughout the winter months. Early in the spring (March or April) the land is plowed to a depth of 6 to 8 inches, with weeds and bean straw thoroughly turned under. The rains that may follow settle the soil and start a new growth of spring weeds. These weeds may then be disked, the land harrowed smooth, then packed for planting.

If the Blackeyes follow a grain or other similar crop, the land should be plowed deeply in the fall before the heavy winter rains. Large clods that may appear in the heavier soil types will slack down during the rainy season. Deep fall plowing or listing permits immediate and deep-soil penetration that reduces loss of water through evaporation and runoff. Where plow sole has formed or where irrigation has compacted the subsoil, fields are frequently subsoiled to a depth of 18 to 24 inches. Subsoiling should be done when the soil is very dry just before the rainy season sets in. Deep fall plowing tends to reduce weeds and to delay their growth. As the season advances, the depth of plowing should be reduced until the late spring plowing is not deeper than 5 or 6 inches. Deep spring plowing causes a loss of moisture and may seriously affect seed germination where the soil is not irrigated previous to planting.

Spacing.—Blackeye rows are usually spaced 30 inches apart for varieties with small vines and 36 inches for those with large vines. Where the soil is soft and fertile, 15 to 25 pounds of seed per acre may be sufficient, but where the soil is less fertile, heavy textured, or has lower water-holding capacity, 25 pounds or more per acre may be needed. The plate planter, 2 or 4 rowed, is commonly employed, but in southern and coastal areas the Ventura-type planter is used. The Ventura planter drops the seed through lifting it from the seed box by means of a sprocket with spokes, each spoke bearing a cup that holds a

single bean which it drops into the planting tube or shoe. No seed injury occurs with use of the Ventura planter, but the plate planter may crack or injure seed when the holes in the plate are too small or when the plate is too thin to accommodate large-sized Blackeyes. The concave wheels of the plate planter compact the soil against the seed, a method that assists in prompt germination. The Ventura planter, on the contrary, leaves the seed in loose soil. Where moisture in the soil is abundant, this method is favorable but where there is insufficient moisture, packing or harrowing should follow planting by the Ventura planter. The depth of planting averages about 2½ inches but can be deeper if moisture conditions demand.

Cultivation is necessary for removal of weeds, but if no weeds appear cultivation is not needed. When irrigation is required furrows are placed between the rows. Weeds that come after irrigation should be destroyed, but if no weeds grow, cultivation is of no measurable benefit. Useless cultivation may destroy feeder roots, growing close to the soil surface, and markedly reduce the crop.

Fertilization.—Application of fertilizers to Blackeyes should be guided by actual tests. Usually animal manures are of pronounced benefit but chemical fertilizers may or may not show a profitable response. Because of the nodules that normally are found on Blackeye roots, the plants are supplied with nitrogen, but the response to phosphate and potash will determine their use. Although considerable plant residue in roots, straw, and leaves is added to the soil, the growing of a winter crop of rye or barley, or even a legume crop to be plowed under sufficiently early to become incorporated in the soil before planting season, has a markedly beneficial effect on Blackeyes.

Crop Rotations.—In successive cropping to Blackeyes a decline in yield and quality occurs which is more pronounced on poor soils than on fertile soils. The reduction in yield appears to be due to three causes: (1) depletion of chemical fertility, (2) reduction of organic matter, and (3) an increase of harmful diseases. The application of chemical fertilizers seems to have little or no measurable affect, but frequently fertilizers applied to a preceding crop favorably affect the following bean crop. When a green-manure crop is grown in the winter period (either legume or nonlegume type) and plowed under sufficiently early to be well rotted, the beneficial effects to Blackeyes are marked. Crop rotations with grain or alfalfa tend to reduce diseases that affect yields.

A common rotation where irrigation is available is the double cropping or the harvesting of a grain or hay crop after which a Blackeye crop is grown. For such practices the early-maturing varieties are used and planted on preirrigated, well-prepared soil from June 15 to July 15. These late-planted Blackeyes, however, are especially subject to rain damage because of the late harvest. After the harvesting of the beans a grain crop is again planted. Double cropping is a drain on soil fertility and should not be long continued without the addition of fertilizers; as much time as possible should be allowed between crops. Annual rotations of Blackeyes with grain crops, either irrigated or on summer-fallowed land, improve the grain without reducing the bean crops.

The new nematode-resistant Blackeye varieties have proved to be a valuable rotation crop with cotton. The effect upon the cotton crop of one crop of Blackeyes has been found to be equal to, or better than, three years of alfalfa in the improvement of cotton yields. The rotation of Blackeyes with potatoes, which

are usually heavily fertilized, produces good yields of Blackeyes; furthermore, if clean culture is provided, volunteer potatoes, which may carry diseases, are eliminated. Where the planting of Blackeyes follows alfalfa, an improvement in the bean crop is seen for several years.

Nodule Cultures.—In all the well-established areas where Blackeye beans are grown, the abundant nodulation occurring provides a prolific source of nitrogen. In such areas nodule cultures need not be applied to the seed, but in new areas where Blackeyes have not previously been grown and where nodules seldom appear, nodule bacteria (*Rhizobia*) must be applied to the seed immediately before planting. Care should be taken not to expose treated seed to the sun, for sunlight quickly destroys nodule bacteria. Temperatures of over 90° F may destroy them entirely. Not only does direct sunlight quickly destroy the bacteria, but also air temperatures above 92° F (Fred *et al.,* 1932, p. 192; Allen and Allen, 1936), which are not unusual, soon ruin a rhizobian culture. Freezing does not kill, but has only a depressing effect on these bacteria and need not be feared in the California-Blackeye areas. Drying out of nodule cultures in the air rapidly destroys their viability but in the soil the cultures remain alive. Two or three years of seed treatment may be required to secure abundant nodulation and should be continued until all light-green leaves are replaced by dark-green leaves. The spread of nodule-forming bacteria from fields that are well inoculated to adjacent fields generally occurs. These bacteria are spread more rapidly in the direction of the prevailing summer winds.

In certain areas Blackeyes may become inoculated from cultures on other legumes, but the best results are secured from cultures that have previously shown good adaptation.

The cowpea species of nodule bacteria nodulate a large number of legumes including the mung bean, lima bean (although not always), tepary bean, adzuki bean, asparagus bean, moth bean, velvet bean, *Dolichos,* beggarweed (*Desmodium purpureum*), Scotch broom, acacia, *Lespedeza,* peanut, tick trefoil (*D. illinoense*), kudzu-vine, pigeon pea, rice bean, and Jack Bean (Pieters, 1927). In the southern part of the San Joaquin Valley, where Blackeye beans are beginning to be grown, no cowpea nodule bacteria are found to occur naturally. In such areas the seed should be inoculated for a number of years, until the soil can be definitely shown to be thoroughly charged. Where no nodules occur on the plants, the seed crop is likely to be light and the foliage a pale green. Soils insufficient in available phosphates, low in water-holding capacity, or with poor textural drainage may prevent the formation of nodules or destroy them on the roots of growing plants after they have been formed. Soils sufficiently low in alkali to permit the growth of Blackeyes also may prevent proper formation of nodules.

In treating the seed, both liquid and dust cultures are successfully used. If other conditions are satisfactory, it is necessary only to touch the seed with the inoculum to secure nodule growth. Best results follow the planting of the seed within 3 hours after treatment. Always be sure the cultures are fresh and viable. The viability and effectiveness of nodule culture may be officially tested (Leonard, 1944). The cost of the nodule-bacteria culture is approximately 20 cents an acre, or the value of 3 or 4 pounds of Blackeye beans at prevailing prices. The returns may be manifold.

Seed Treatment.—When Blackeye beans are planted too early or in soil too cold for normal germination, fungus diseases common to the soil cause a reduction in seed germination or injury to seedlings; a consequent reduction in the vigor of the plants and the crop results. A number of chemical dusts, including Cuprocide (copper oxide), Ceresan (ethyl mercury phosphate), Semesan (hydroxymercurichlorophenol), and other mercurial dusts have been successfully used, but the dust that has given the best results with the least injury to seed and seedlings is Spergon (tetrachloro-*p*-benzoquinone), a nonmercurial dust.

Various seed protectants dusted upon Blackeye seed planted on April 13 near Keyes, Stanislaus County, while the soil was still cold, gave the results shown in table 6.

TABLE 6

Seed Treatment* of Bean Plants with Chemical Dusts per 100 Feet of Row†

New improved Ceresan	Plants treated with Ceresan	Plants treated with Semesan	Check plants	Plants treated with Cuprocide	Plants treated with zinc oxide	Check plants
number	*number*	*number*	*number*	*number*	*number*	*number*
81	87	68	37	68	101	41
88	83	84	52	69	83	21
81	84	88	39	109	91	34
77	58	95	82	91	104	39
83	63	98	56	100	112	49
..	..	..	58	...	...	44
..	..	..	41	...	...	26
..	..	..	...	...	...	28
Average						
82	75	86	45	87	98	35

* From experiments conducted on the Egbert Jones farm by L. O. Leach of the University Farm, Davis, and by Albert G. Volz, Agricultural Extension Service.

† Comparative stands of 100 feet of row under field conditions replicated five times.

Although some variations appeared in the effectiveness of the fungicides, about twice as many plants survived as did in the untreated, or check, plots. Later tests demonstrated the superior effectiveness of Spergon. Spergon dust is applied at the rate of 3 ounces per 100-pound sack by the same methods used for dusting grain. It is not poisonous to human beings or animals (Leukel, 1942). When a nodule-forming culture is necessary, the treatment of the Blackeye seed with Spergon does not materially reduce the effectiveness of the nodule bacteria (Burton and Erdman, 1941).

With a rise in soil temperature, the attacks of soil-borne damping-off diseases of seed decline so rapidly that the chemical dust may show no marked effect over untreated seed. This rise in soil temperature usually occurs about May 20.

Irrigation.—Irrigation is necessary for successful production of Blackeyes in the whole San Joaquin Valley, in the greater part of the Sacramento Valley, and in southern California. Irrigation practices vary according to the time of planting. When Blackeyes are planted early (late April to May 20), the soil, if properly prepared by earlier cultivations, retains sufficient moisture from the winter rainy season to germinate the seed readily and to promote normal growth until the plants reach the third or fourth leaf. Previous to this time the rows are furrowed to carry the streams of water. Irrigation should not be postponed until the plants suffer. This point is indicated when the leaves become

dark green instead of a normal, healthy bright green. In any event, irrigation should not be delayed beyond the blossoming period. From the beginning of blooming until the first crop of pods is well set, the plants should be fully supplied with water. After this period, usually no further irrigation is required unless the soil has poor water-holding capacity. The farmer who is familiar with his soils can best determine the number of irrigations required.

Where the furrows are very long the water may take many hours to reach and wet the lower end. Under these conditions, the upper parts of the furrow may be saturated for many hours. Saturated soils, with the air driven out, re-

Fig. 2.—Blackeye 7711 on unirrigated silt loam. Davis, California.

tard the growth of the roots, favor fungus diseases, and tend to destroy the nodule bacteria that requires abundant supplies of oxygen. The remedy lies in shortening the length of the furrow in order to reduce the period of saturation in the soil.

Except for the irrigation districts in northern San Joaquin Valley, where an abundance of gravity water is always available, the furrow method of irrigation prevails. The irrigation districts with abundant gravity water use the flooding system. This system consists of borders from 40 to 50 feet wide, the width dependent upon the condition of the soil into which a flood of water is to be turned for irrigation. This water soon drives the air from the soil, although in sandy soil the water does not remain long on the soil surface. Because of the ease and the cheapness of this method, its practice is continued even though it has caused the destruction of Blackeyes by fostering cowpea wilt, stem canker, and other fungus diseases to be described later (p. 41–44). The Blackeye, unlike the common bean, does not drown under heavy flooding and has produced abundant crops under this method of irrigation.

Growing Blackeye Beans by Dry Farming.—Growing Blackeye beans by the dry-farming method is practiced in certain areas where irrigation water is not obtainable. The only moisture available for the crop comes from the winter rains. It is held in the soil by early plowing, which tends to catch and retain rain water. Shallow cultivations should follow, to destroy weeds and to prepare a good seed bed. In dry farming, early planting is practiced (late April to May 20) with later cultivations intended solely to destroy weeds (Veihmeyer and Hendrickson, 1930). Usually, soils that have lain summer fallow after grain harvest are used for the dry farming of Blackeyes. Soils with good water-holding capacity are essential. The yields under summer-fallow conditions (fig. 2) are much lighter than those on irrigated soils, but the expense of production

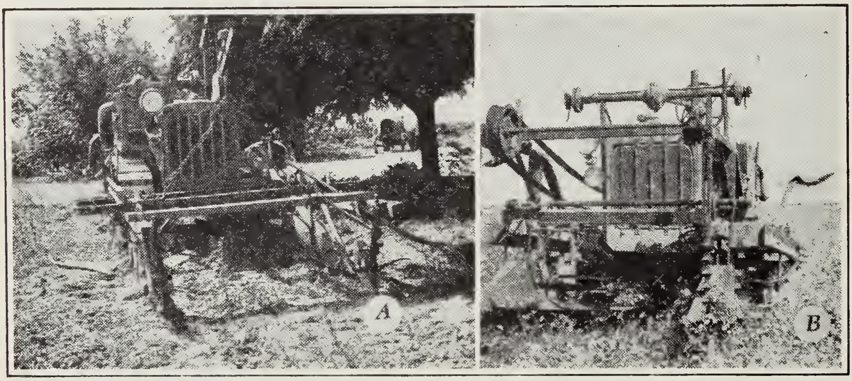

Fig. 3.—Four-row tractor Blackeye-bean cutter: *A*, common cutter; *B*, cutter with an upright mower bar.

is much less. Fall rains seldom disturb fields planted so early. Frequently, the Blackeye crop is followed by a grain crop which is much improved in yield and quality.

Harvesting.—Harvesting begins as soon as the major part of the pods have turned straw color. Because the Blackeye will continue to grow until killed by frost, a harvest date must be chosen that will include the greater part of the crop. If harvesting is delayed until the late-appearing pods are ripe, discoloration from dew and fog may occur on the beans that are long past maturity, with consequent lowering of grade. Since the quality may be impaired further by immature, undersized beans from late-matured pods, it is best to disregard them. In those pods where green, or immature, seeds are found, the beans will mature in the pods into marketable quality if the black "eye" is definitely formed. Beans that have not matured to this stage will shrivel; later they will be blown out in threshing.

Just below the surface of the soil, the vine roots are cut with bean cutters which consist of long steel blades set at an angle. A 4-row cutter (figs. 3*A*, 4, 5) drawn by a wheel tractor is preferred, but many 2-row, horse-drawn cutters are used in the smaller fields. A colter, or an upright mower bar (fig. 3*B*), cuts the vines between each cutter swath. The cutting is begun early in the morning and is continued until the pods show signs of shattering, then it is discontinued until the following morning. An ordinary, side-delivery hay rake follows the

cutter. Usually eight rows are piled together in a windrow to dry for the pickup combine. The combine, which may be self-propelled or tractor drawn, has its own separator engine that can be regulated to suit the condition of the straw. When stationary threshers are used, the beans are piled in shocks and hauled

Fig. 4.—Cutting a field of Blackeye 8147 by power cutter for heavy vines.

Fig. 5.—Blackeye 7711, a large viny variety, harvested by a power cutter.

to the thresher. The cylinders should run much slower than those of grain threshers or approximately 800 revolutions per minute (fig. 6). The speed of the cylinder should be regulated and constantly adjusted, according to the condition of the straw, in order to avoid the cracking of beans. Cracked beans greatly reduce the price. The cracked and split beans removed on recleaning have a low value for stock feed only.

For small acreages, the beans may be rolled out on canvases or on smooth,

hard-packed ground. While the wheel tractor-drawn roller or disk (fig. 7) is threshing on one threshing bed, the other bed is being prepared. The threshed beans are shoveled into a pile in the center of the bed and later cleaned by a custom-cleaning outfit. The sacked beans are hauled to a central warehouse, where they are recleaned and placed in 100-pound sacks for marketing.

Fig. 6.—Harvesting Blackeye beans in Sacramento Valley.

Fig. 7.—Rolling Blackeye beans in small fields.

USES OF BLACKEYE BEANS AS COVERCROP AND FORAGE

Since Blackeye beans are cowpeas, they can replace other varieties of cowpeas as green manure and forage crops. The distinction between cowpeas and Blackeyes consists entirely in the uses to which they are put. Blackeyes are grown primarily as a seed crop with forage and green manure as secondary uses. The usual and best practice in harvesting Blackeyes is to spread the straw behind the pickup combine where it is disked into the soil to decompose and rebuild the soil fertility for the succeeding crops. Frequently, the Blackeye fields are pastured by stock. The baled or stacked straw affords good feed for penned or corral-fed stock. Blackeyes and cowpeas are seldom used in California for hay,

but in many soils where a seed crop is not successful good yields of hay may be grown as a summer catch crop.

If there has been considerable wastage, the Blackeye seed or unthreshed pods may be reclaimed by hogs, which do not eat uncooked common beans or lima beans. Similarly, poultry consume Blackeyes although they refuse ordinary beans.

At the University Farm at Davis, California, E. H. Hughes, of the Division of Animal Husbandry, used Double Dwarf milo and Blackeye beans for feeding hogs. Feeding two lots of 41 pigs each, the milo produced 428 pounds of pork per acre, whereas the milo and Blackeyes produced 447 pounds. The average daily gain for the milo diet was 0.9 pound per pig and for the milo and Blackeyes 1.26 pounds. The milo-fed pigs averaged 116.4 pounds after 35 days and the milo with Blackeyes, 117.8 pounds in 26 days. When rolled barley and whole milo were fed, it took 342.6 pounds to produce 100 pounds of pork to only 303.3 pounds of the milo and Blackeyes. When the final part of the experiment was concluded, 50 per cent of the milo-fed hogs were ready for market as against 75 per cent of those fed milo and Blackeyes. The superiority of the milo and Blackeye mixture is ascribed to the protein furnished by the Blackeyes (Hughes, 1944).

Where a cowpea crop is to be pastured, the most prolific and hardy varieties are the Brabham and Iron, especially in areas where the soils are infested with root-knot nematodes. On red soils, where Blackeyes usually do not produce the best yields, the Red Ripper variety is hardier and more prolific. In other soils not infested with nematodes and fungus diseases the Whippoorwill variety gives good yields. None of these varieties of cowpeas, however, has become established as a forage or green-manure crop because of the high price and difficulties in securing seed. Susceptibility to nematodes and diseases has prevented the Red Ripper, Whippoorwill, and similar varieties from being generally used or recommended. The low yield of seed for Brabham and Iron varieties discourages the farmer from growing these crops in competition with the Blackeye.

Seed of the Brabham and Iron varieties imported from cowpea areas on the Atlantic Coast has frequently been found to produce crops highly susceptible to nematodes and cowpea wilt. These varieties when pure are highly resistant to such diseases, but through field hybridization in the eastern areas the normal resistance has broken down. Practice has revealed that recently created varieties of disease-resistant Blackeyes can readily replace these imported cowpeas with less cost for seed and with better results where green manure or forage crops are desired. Blackeye 1, Blackeye 7, Blackeye 8149, Chino 2, and Blackeye 7711 can be used for forage with progressively higher yields in the order given. Blackeye 7711 was bred especially to combine the qualities of disease resistance, high yield of marketability, and forage. It matures about 3 weeks later than the purely seed types, however, or in about the same length of time as Brabham and Iron. Because of the later maturity and vigor of Iron, Brabham, and Blackeye 7711, they may be pastured two or three times. Through the selection of seed from available, disease-resistant Blackeye varieties, the purposes of forage or green manure for a selected area or season can be satisfactorily met.

INTERCULTURES WITH BLACKEYE BEANS

Interculture of row crops with legumes has always been and still is practiced by American Indians. It has been suggested that the nonlegume crop secures immediate benefit from the nitrogen gathered by the nodule-forming bacteria. Experiments made in the United States to test this theory have not been very conclusive. Possibly lateritic soils of the tropics would respond favorably, but at present only such a well-established practice as the planting of beans in the rows of corn substantiates the theory (McClelland, 1937, 1940). Tests made in Arkansas with the planting of cowpeas in the same row with corn showed "where cowpeas were in the same row with corn, the increase was 15.5 per cent, where cowpeas were in wide corn middles (58 inches), the increase was 5.9 per cent, where the cowpeas were in normal corn middles (44 inches), the increase was 9.8 per cent." Effect on the yield of succeeding crops of oats and cotton was in the same proportions for three separate substations. The greatest benefits from interplanting cowpeas in corn occurred when the cowpeas were planted in the row with the corn. Crops of corn and cotton following these inter-cropping tests with cowpeas were similarly benefitted.

Such Blackeye crops would have to be used as pasture, for Blackeye seed could not otherwise be harvested profitably. The large viny varieties of Blackeyes make excellent hay but do not appear to be used to any extent for this purpose. Where Blackeyes are grown in the row with very tall and rank-growing corn or sorghums the Blackeyes may be suppressed by the shade.

BLACKEYE SEED AND VARIETAL PURITY

The varietal purity of Blackeye seed, which made little difference as long as the Blackeye markings and quality were obtained, has been altered radically by the inroads of disease and by the creation through breeding, of disease-resistant varieties. To hold the qualities of disease resistance, adaptation, character of seed, and other desirable features, it is necessary to maintain the purity of the variety. This is provided for by the operations of the California Crop Improvement Association, which is responsible for the certification of the seed of varieties listed with them (Anon., 1944–45).

BREEDING FOR DISEASE-RESISTANT BLACKEYE BEANS

With the increase of Blackeye production in California, diseases to which the beans are susceptible began to appear. The most destructive were cowpea wilt caused by *Fusarium oxysporum* f. *tracheiphilum* (fig. 8), root knot caused by the nematode *Heterodera marioni,* and charcoal rot caused by *Sclerotium bataticola* (*Macrophomina phaseoli*). Although cowpea wilt may attack Blackeyes in any part of the state, the virulence of the attack is accentuated by the quantity of irrigation water used to grow the crop. In areas including southern California and the southern San Joaquin Valley, where pumped water is distributed in furrows, cowpea wilt is of minor importance. In the Turlock, Modesto, Merced, and Manteca areas, where gravity water is abundant and cheap, flooding of Blackeye fields is the common practice. Here cowpea wilt is a major factor in Blackeye production and bids fair to destroy the industry completely.

In 1929 the writer was assigned the task of breeding Blackeye beans resistant to this destructive disease.

Before undertaking the breeding work, tests of the resistant stocks indicated that the Iron cowpea (Orton, 1902, 1908, 1911; Webber and Orton, 1902) was

Fig. 8.—Common California Blackeye beans destroyed by cowpea wilt, root-knot nematodes, and charcoal rot.

Fig. 9.—The Iron cowpea, a disease-resistant variety.

resistant to cowpea wilt, charcoal rot, and root-knot nematode. The Iron cowpea is unlike the Blackeye in many characters (figs. 9 and 10). It is late in maturing, unusually viny, and yields a small crop of very hard, small, brown seeds unfit for human consumption. Like the California Blackeye, however, the Iron cowpea is resistant to shattering.

Breeding for disease-resistant varieties cannot be considered as permanent when a resistant variety is secured. Not only is the variety itself subject to variation through mutation and field hybridization (Mackie and Smith, 1935) but the disease itself is subject to the same variations. It may be that a highly resistant variety (immunity is rarely attained) may suddenly show marked susceptibility after having been resistant for a long period. Such conditions are usually caused by a newly risen and virulent form of the disease. This appears to have been true of California Blackeye 5. Although this variety did not have the highest possible resistance, it did produce satisfactory crops, but now it shows considerable susceptibility to cowpea wilt, although continuing its resistance to root-knot nematode. At present all the nematode-resistant hybrid

Fig. 10.—Iron cowpea with a strong vigorous root.

varieties appear fixed for nematode resistance, but it has been shown that the root-knot nematode has a number of strains that vary in virulence (U. S. Agricultural Research Administration, 1943); these strains appeared when some of the nematode-resistant beans were tested in the southern states. Conversely, nematode-resistant bean varieties of the southern states when grown in California have succumbed to nematode attacks. In order to note the changes in the battle of resistant host to attacking parasite, constant vigilance must be maintained by renewed breeding against the parasitic forms of these diseases as they appear.

TECHNIQUE OF BREEDING

The first artificial crosses between Iron and the Blackeye were made between the hours of 9 a.m. and 4 p.m., during the warmer part of the day, upon the advice of prominent cowpea breeders (see also Spillman and Sando, 1930; Oliver, 1910; Capinin, 1935). Of more than 2,000 crosses made at Hilmar, Merced County, only one was successful. In the following summer, similar crossings were made at Davis. Here artificial crosses were begun at early daylight and continued until 4 p.m. From sunup until about 8:30 artificial crossing was very successful, but before and after these periods, no viable crosses

were obtained. Because the pollen of cowpeas does not float in the wind, it was not necessary to cover the emasculated flowers. Within 24 hours after the crossing, which was made immediately after emasculation, the successful ones could be detected.

Natural crossing in Blackeyes rarely occurs in California (Mackie and Smith, 1935) because the pollen, being sticky and heavy, does not float in the wind. The dry air in the areas where the Blackeye is grown favors immediate pollination. In many of the southern states, where humidity is high throughout the day and night, considerable cross-pollination occurs. For this reason, seed of cowpea varieties of southern origin, grown for forage and green-manure crops in California, have been found unsatisfactory. This applies especially to

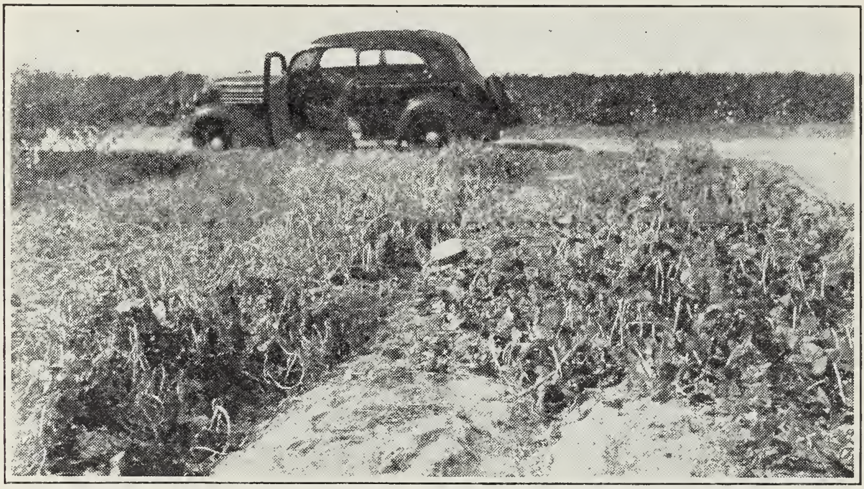

Fig. 11.—Right, Iron cowpea resistant; center, common California Blackeye bean susceptible and dead; and left, disease-resistant hybrids. Shafter, California.

such varieties as Iron, Brabham, and Victor (Piper, 1924), which are grown on soils infested with root-knot nematodes and cowpea wilt. The stocks of these varieties used for breeding were purified and tested under severe disease attack. The Victor variety was rejected because of extreme shattering of the seed (Hayes and Garber, 1921) and the Brabham because it was less disease resistant than the Iron, which is the parent of both these varieties (Piper, 1912). Iron does not shatter, but it is a poor yielder in spite of its high disease resistance.

The tests of the F_1 and succeeding generations were made on the farm of J. J. Anderson, near Hilmar, in soil where cowpea wilt, root-knot nematode, charcoal rot, and other diseases had long attacked and injured the Blackeye crop. At close intervals, susceptible California Blackeyes were planted throughout the plots in the breeding tests to keep the attacks of these diseases at full virulence (fig. 11). The common practice of flooding the crop was followed to maintain the maximum disease attack.

To secure a disease-resistant Blackeye as nearly as possible like the Blackeye of commerce, the F_1 plant (fig. 12) was crossed back to the California Blackeye. The backcrossing of F_1 plants was continued to the fourth and sixth gen-

erations. Only those crosses made on disease-resistant plants were continued. Most of these backcrossed survivals varied in many respects from the California Blackeye, including maturity, size, and shape of vine and seed.

FACTORS INVOLVED IN BREEDING FOR DISEASE RESISTANCE

Size of Seed.—Because of different genes for size carried by the parents, it was possible to increase the size of the seed to that of both parents combined. The largest-sized seed, however, was usually too coarse, inclined to split and to discolor, and was frequently twisted or otherwise undesirable in shape. Excessively large seed usually has a hollow space between the two cotyledons, which induces excessive cracking and splitting during threshing.

Fig. 12.—An F_1 hybrid between California Blackeye bean and Iron cowpea.

Shape of Seed and Quality of Seed Coat.—Variations from the desired kidney shape (fig. 13) including long, cylindrical, blunted ends, flat, twisted, and other types were eliminated, as were variations from the bright white color desired, such as cream, yellow, gray, or dappled. Skin texture expressed in the size and form of the wrinkles from coarse to smooth was similarly made to conform to the accepted trade standards. The seed coat of the Blackeye is sharply divided into the white area and the small black area surrounding the hilum, called the "eye." The desired white seed coat is finely wrinkled whereas the black seed coat forming the "eye" is smooth. The difference in wrinkling lies in the palisade cells, which are turgid and regular for the colored area and irregular in form and turgidity for the wrinkled white seed coat (Mann, 1914). The wrinkled seed coat imbibes water much more rapidly than does the colored, smooth seed coat; this greatly improves the cooking and eating qualities over the self-colored, smooth seed-coated cowpeas. Although cracked skin frequently was caused by cultural practices and weather conditions, it was found to be inherited and controlled, to a large extent, by breeding.

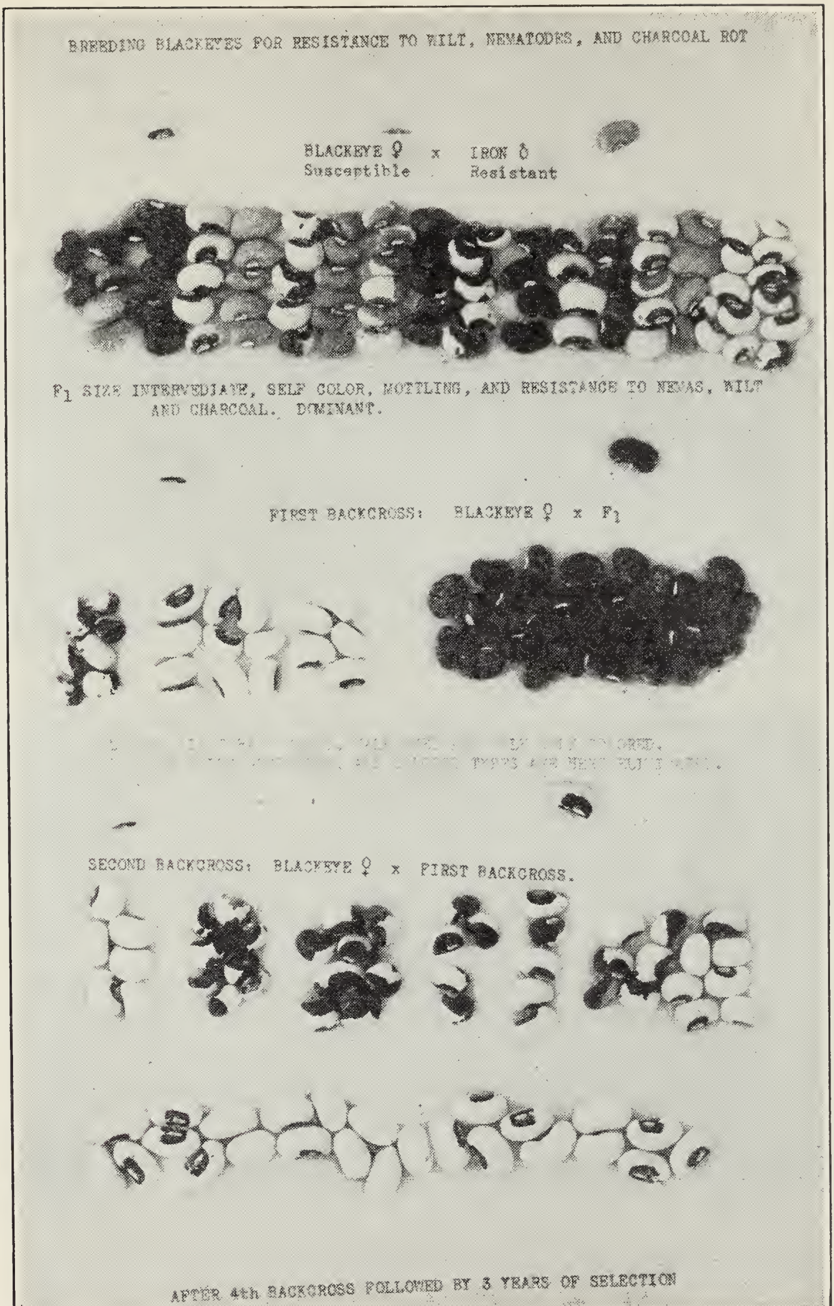

Fig. 13.—Breeding Blackeye beans resistant to cowpea wilt, root-knot nematode, and charcoal rot.

Vine Shape and Size.—Vine shape and size are important to the farmer. Large flat vines that appear early in the season prohibit the operations of the cultivator and are also difficult to harvest. The fact that the shape and size of the vine is inherited (figs. 9, 14, and 15) permits staple selection of the desired

Fig. 14.—Blackeye 8149. Butte County, California.

Fig. 15.—California Blackeye no. 5 (8145), earliest of California Blackeye × Iron hybrid. It is resistant to root-knot nematode and cowpea wilt, but is susceptible to charcoal rot.

oval, upright types (Harland, 1919*b*, 1920). Although bush types found in the common bean and lima beans have not been found in the Blackeye, an oval, upright form, similar to the California Blackeye, has been isolated frequently. This form is recessive, as are the bush types, and therefore remains fixed. The flat and intermediate forms were eliminated by selection except where the large viny types were continued in order to form forage or covercrop varieties.

Maturity.—Time of maturity is definitely inherited. In the F_1 generation, late maturity was found to be dominant and identical with that of the late Iron parent, but in the F_2 and later generations early-maturing types were isolated as recessives. When the inheritance of seed size, seed shape, seed color, seed-coat wrinkling, maturity, and vine shape and size were fixed in the hybrid varieties, the inheritance of disease resistance under different cultural conditions was carefully studied.

INHERITANCE OF CHARACTERS FOUND IN HYBRID BLACKEYES

The inheritance of seed-coat colors, patterns, and eyes has been well worked out by several plant breeders and geneticists (Orton, 1908; Spillman and Sando, 1930; Harland, 1919*a*; Capinin, 1935) checking their behavior. These inheritances were checked but no outstanding differences were noted.

Disease resistance in the various crosses behaved likewise, establishing the dominance of disease resistance in the F_1, or first generation (fig. 12). The ratio of resistance to diseases in the following generations was impossible to determine owing to three major and many minor diseases always present and active. The use of the backcross method of breeding to secure rapidly the qualities of the desirable Blackeye parent further prevented genetic studies of disease inheritance.

Although the Iron cowpea shows only slight formation of small nematode galls, the hybrids of Iron and susceptible varieties do not display the same high resistance. Another species of the same genus (*Vigna lutea*) has proved, over many years of tests, to be free from the numerous diseases attacking the cowpea and entirely free from nematode galls (fig. 16). For several years, attempts to secure crosses have failed. It may be, however, that other methods of crossing will be found to be successful. Other species of this genus from Africa, where it is indigenous, may be found that could be successfully used in breeding for disease resistance in cowpeas.

MODE OF INHERITANCE OF CHARACTERS

In crossing the California Blackeye and the Iron cowpea, the Blackeye was used as the female parent because of its greater number of available blossoms, the large size of its flowers, and the more certain setting of its seed.

The California Blackeye has a normal size index of 24.0, a kidney-shaped seed with a finely wrinkled seed coat of bright white, except for a small black "eye" surrounding the hilum. The leaves are light green and remain active until killed by frost or diseases. The pod is green, thin skinned, bears 8 to 10 seeds, and is nearly straight with but slight curving. It does not shatter under normal conditions. The vine is small, oval, upright, and bushlike. It is best adapted to rows spaced 30 inches apart.

The Iron-cowpea seed has a size index of 11.0, is kidney shaped with a thick, tough seed coat devoid of wrinkles, and is tan or brown. Many hard seeds are formed that survive the winter in the soil and volunteer in the spring. The vine is large, wide spreading (12 feet or more under good soil conditions) (fig. 9), oval, upright, and bears very dark-green leaves. The root is extremely large (often 3 to 4 inches in diameter at the maximum) (figs. 10 and 17), with very

thick bark in which disease resistance appears to be located. The size and the deep penetration of the root indicate a perennial habit that cannot be determined because frost ends the life of the plant before the end of the first year. The pods are almost straight, shatter resistant, and bear from 10 to 14 seeds. The Iron cowpea is highly resistant to charcoal rot, root-knot nematodes, cowpea wilt, and cowpea mosaic, as well as to several other minor diseases.

The F_1, or First Generation.—The haploid chromosome number of the cowpea is 12 (Senn, 1938). The size of the F_1 seed is intermediate or almost exactly half the size of the combined weight of both parents (fig. 13). The shape of the

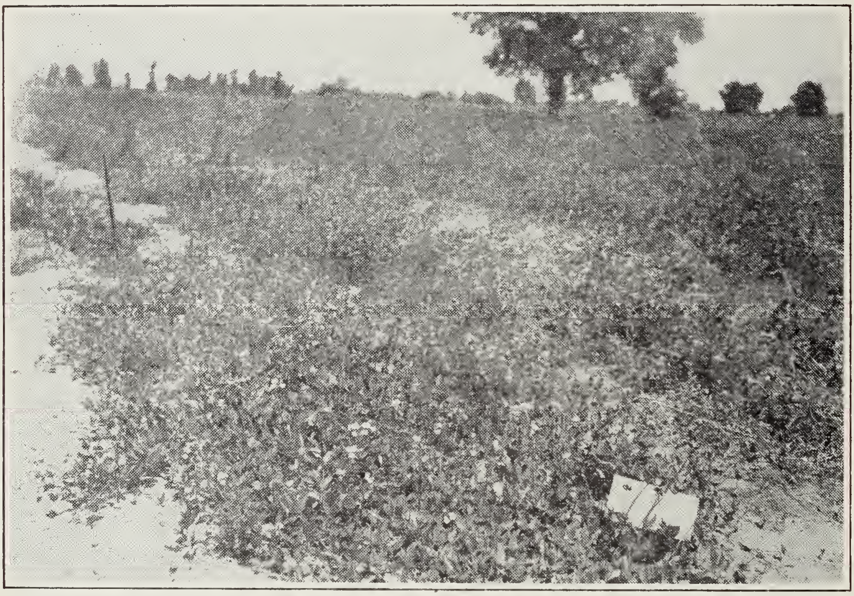

Fig. 16.—*Vigna lutea*, a species closely related to cowpeas. It is resistant to fungus diseases, red spider, wireworm, and root-knot nematode. No viable crosses with Blackeye beans have been secured, even with years of trials.

seed is similar to that of both parents, namely kidney. In color the seed coat is black, with small, reddish mottlings or flecks expressive of the dominance of both black color and mottling. The seed coat, like that of the Iron parent, is smooth, thick, and devoid of wrinkles. The size and vigor of the vine are greater than that of the Iron parent (fig. 12).

In form, the vine closely resembles the Iron parent; the leaves are dark green, the roots large with thick bark, and the maturity late—all characters of the Iron. The pods are nonshattering like those of the Iron parent; and the yield, like the size of the seed, equals the combined yield of both parents. Disease resistance in the F_1 is exactly like that in the Iron.

The F_2, or Second Generation.—The size of the F_2 seed varies from smaller than the Iron to one half larger than the Blackeye parent, indicating at least two factors for size. The shape of the seed varies widely from almost round to long cylindrical with twists, blunt ends, and splits. Multiple factors for shape and size are indicated.

Color caused by anthocyanin and a melaninlike substance (Mann, 1914) is represented in several forms: solid or self-colored—black, brown, or buff, maroon, blue or purple, red, cream and white, and mottled, including Holstein, flecked, eyed (colored about the hilum) in many sizes and forms. The mode of inheritance of these colors has been clearly set forth by Spillman and Sando (1930) and Harland (1919*a*).

The size and shape of the vine varies widely. The mode of inheritance could not be accurately determined because of multiple disease attack, but forms appeared, varying from the bushlike to the very flat, prostrate types with all kinds of intermediates. Only those adapted to tillage machinery were preserved.

Fig. 17.—Roots of Blackeye hybrids (California Blackeye × Iron). Left to right: Chino 3, Blackeye 8147, Blackeye 8149, Blackeye 7711, and Chino 2.

The eyed character was inherited at a 3:1 ratio of self-colored to eyed types, the eyed form being recessive (Spillman, 1911). At least 13 different eyed forms were noted, many of which were heterozygous and separated usually in a monogenic ratio. The small blackeye form, desired by the trade, was found to be recessive to the large and variable-shaped eyes and was easily maintained in the backcrossing.

Rusty, yellow, and gray coloring in Blackeyes caused by pigments in the palisade cells of the seed coat or in the layer cells directly below them, is inherited. Some hybrids, sound in other respects, were rejected for this reason. Dark-green leaf color appeared to be linked with colored seed coats. Yield and size of vine were not linked or definitely associated. No attempt was made to determine mode of inheritance for maturity, but fixed selections of wide variation were secured, ranging from a period shorter than the early Blackeye parent to later than the late Iron parent.

Anthocyanin color (red or purple) in pods, stems, and leaves, is inherited. An absence of this coloring results in a pure light green. Inheritance ratios in disease resistance could not be genetically determined because of constant multiple-disease attacks.

Beginning with the fourth and sixth backcrosses, thousands of disease-resistant plant selections were tested under severe disease attack in the plant-to-row

plots. The best of these were increased and placed with bean farmers. These first distributions were not fixed in all characters, but further selections involving hundreds of plants from each variety were tested. These followup tests resulted in varieties much improved in resistance to disease attack, especially cowpea wilt.

FACTORS AFFECTING DISEASE RESISTANCE TO COWPEA WILT, CHARCOAL ROT, AND ROOT-KNOT NEMATODE

Cowpea wilt is not only carried in the soil but is seed-borne from outside contamination, especially during threshing (Kendrick, 1931). Considerable variations in resistance in the new hybrid varieties were found for different

Fig. 18.—Background of pigeon peas resistant to root-knot nematode. Foreground, partially resistant Blackeye hybrids and one highly resistant Blackeye hybrid at back.

localities and different cultural practices. Before wilt-resistant varieties were made available, the usual practice in the Blackeye area of the San Joaquin Valley consisted in preirrigating the land, then cultivating and seeding. No further irrigation was given. The resulting crop depended upon the fertility of the soil, its water-holding capacity, and the degree of soil infestation from wilt. The same conditions prevailed with root knot caused by the root-knot nematode. Where these two diseases occurred, subsequent irrigation after the Blackeye crop was up usually caused the destruction of a large part of the crop. Under dry-land conditions (not irrigated) cowpea wilt and nematode injury usually were not markedly apparent. With the introduction of new disease-resistant varieties, irrigations were applied in ever-increasing numbers and with larger quantities of water after the Blackeyes came up. Because of the abundance and cheapness of gravity water, the flooding method of irrigation is used in the San Joaquin Valley irrigation districts of Manteca, Modesto, Turlock, and Merced. Flooding not only weakens the vines by depriving the roots of oxygen for a period, but provides the most favorable conditions for cowpea wilt, nematodes, and many other diseases (fig. 18). In the counties of

the southern part of the San Joaquin Valley and in southern California, where the water is furnished by pumping from wells, the furrow method of irrigation is practiced; this method uses a much smaller quantity of water and does not materially disturb the supply of oxygen to the plant roots. In areas thus irrigated, the disease-resistant varieties showed no measurable loss in yield, although evidence of cowpea wilt and nematode attack was always present.

Charcoal rot depends on entirely different conditions of soil and temperature than do cowpea wilt and nematodes (Tompkins and Gardner, 1935). High water content of the soil and low soil temperatures that follow depress the charcoal-rot fungus, but relatively dry soils and high temperature favor it. For these reasons, charcoal-rot causes severe damage to Blackeyes in unirrigated or lightly irrigated soils. Charcoal-rot spores are widely distributed, making attacks possible wherever temperature and moisture conditions are favorable.

Nature of Resistance.—The resistance to cowpea wilt and root-knot nematodes appears to be caused by suberin, a substance common to most plants. The Iron cowpea has the ability to rush suberin promptly to the wounded area from surrounding cells, already high in suberin content, in sufficient quantity to check the disease attack. The cowpea-wilt fungus enters the plant through the root hairs or surface of the roots broken by diseases such as stem canker (sore shin), or by mechanical injury. The root-knot nematode penetrates the cortical tissue and fastens itself upon the woody, or stelar, structure of the stem where the greatest injury occurs. In resistant varieties, like the Iron and its hybrids, the nematode, soon after entering the soft cortex, is met with highly suberized cell walls that effectively prevent the nematodes from reaching the stele, or woody stem.[5] The ability of the Iron to suberize cortical cells appears to be heritable and therefore transmittable to its hybrids. Resistance to cowpea wilt is dominant at the proportion of 3 resistant to 1 susceptible (Hawthorne, 1943).

Charcoal rot caused by *Sclerotium bataticola* (Mackie, 1932) has not been found to attack the Iron cowpea except where the cortex has been mechanically penetrated to the stele. Where such an injury occurs, the vine may be severely damaged by the fungus. In hybrids of Blackeye and Iron, many were secured that are resistant to charcoal rot, cowpea wilt, and nematode attack, whereas others were found to be resistant to cowpea wilt and nematodes but susceptible to charcoal rot. For example, California Blackeye no. 5 is resistant to cowpea wilt and nematodes but susceptible to charcoal rot, whereas California Blackeye no. 1 is resistant to all three. Apparently resistance to cowpea wilt and charcoal rot is attributable to different factors. Dry soils and high temperatures favor charcoal rot (Kendrick, 1933; Tompkins and Gardner, 1935), whereas soils naturally moist or irrigated repress charcoal attack which is caused, undoubtedly, by the lowering of temperatures through evaporation.

In reducing the number of Blackeye hybrid varieties, selection for disease resistance, high yield, good marketing quality of seed, early maturity, resistance to shattering, and for small to medium size of vines, was rigidly applied. Some hybrids produced very high yields but were dropped because of poor quality of seed or poor disease resistance. The old California Blackeye possessed all the desirable qualities (Morse, 1920*a*), except disease resistance, and

[5] Arzberger, E. G. A comparative morphological study of cowpea roots resistant and nonresistant to nematode infestation. Unpublished manuscript.

was used as the ideal to be attained in the disease-resistant hybrids. None of the hybrids possessed superior yielding ability to the California Blackeye; this fact was shown repeatedly when none of the three diseases attacked it.

Tests with Disease-Resistant Blackeye Hybrids in Other States.—The major market for California Blackeyes is found in the southern states, where they are consumed or used as seed. The diseases that attack Blackeyes in California likewise occur in the southern states; it follows naturally that farmers in these states would expect the disease-resistant hybrids that were successful in California to be successful in the south. The producers of resistant varieties in California hoped to find a profitable market for their seed. In anticipation of these demands, the most promising Blackeye hybrids, still somewhat heterozygous, were placed with the experiment stations in eleven of the southern states for testing.

TABLE 7

Maturity of Sixteen Hybrid Varieties Compared with California Blackeye 8274

Variety no.	Days required beyond those of Blackeye 8274	Variety no.	Days required beyond those of Blackeye 8274
8274 (common California Blackeye)	0	8149	6
8130	4	8152	8
8135	10	Chino 1 (Calapproved as California Blackeye 1)	4
8137 (Calapproved as Blackeye 7)	10	Chino 2	5
8140	8	Chino 3	6
8145 (Calapproved as California Blackeye 5)	0	20-20	6
8146	7	M 32	8
8147	6	7711	14
8148	6		

The difficulties arising from attempting to adapt varieties bred and tested for adaptation to California conditions, at once became apparent. Sandy and loamy soils are exclusively used for Blackeyes in California, whereas many heavy soils are planted to cowpeas and Blackeyes in the South. The dry, rainless, growing season of California contrasts sharply with the summers of the southern states where the rainfall is heavy. The rainy summers foster many diseases, including bacterial blights, leaf spots, mosaics, and root rots, which do not occur in the dry California summers. Cowpea wilt and root-knot nematodes, which do occur in both areas, are known to include a number of forms, some of which are not common to either area. Charcoal rot normally does not appear in the perfect form in California but does appear in the eastern areas.

The Iron, or disease-resistant parent, besides being resistant to cowpea wilt, common root-knot nematode, and charcoal rot, has also been found resistant to cowpea mosaic and bacterial blights.

If the hybrids of California Blackeye and the Iron cowpea in a heterozygous condition could be tested for adaptation under eastern or southern conditions, the seed could be produced abundantly in California where the yields appear to be much higher. Seed produced in rainless summers will be free from bacterial blight, from many leaf spots and other diseases until reinfested under southern conditions.

In view of these preliminary tests in the southern states it appears inadvisable to import in large quantities seed of California-produced disease-resistant varieties without dependable tests under southern conditions. Tests conducted over several years in northeastern Texas (Johnson, 1944) with these hybrids and the plant selections from them, established outstanding disease-resistant varieties of high productivity and seed quality. In recent years, however, the demand for seed of the disease-resistant Blackeye 5 has increased in the southern states to the extent of several carloads a year.

TABLE 8

Fields of Blackeye Hybrids Compared with Common California Blackeye 8274 on Farms in Merced and Stanislaus Counties, 1939

Variety no.	Yield per acre on farm A at Keyes	Percentage yield of hybrid to California Blackeye 8274	Yield per acre on farm B at Hilmar	Percentage yield of hybrid to California Blackeye 8274
	100-pound bags	*per cent*	*100-pound bags*	*per cent*
8274 (common California Blackeye)	10.1	100	—*	—
8130	25.6	353	19.9	—
8135	19.0	188	17.2	—
8137	14.9	147	23.2	—
8140	24.6	203	21.6	—
8145	16.6	164	25.1	—
8148	—*	—	20.4	—
8149	25.4	251	27.5	—

Variety no.	Yield per acre on farm C at Winton	Percentage yield of hybrid to California Blackeye 8274	Yield per acre on farm D at Hilmar	Percentage yield of hybrid to California Blackeye 8274
	100-pound bags	*per cent*	*100-pound bags*	*per cent*
8274 (common California Blackeye)	12.0	100	8.6	100
8135	24.0	200	18.6	211
8137	21.0	175	10.1	117
8140	22.5	187	32.4	380
8145	21.0	175	15.0	174
8149	19.0	158	22.3	260

* Dashes indicate data not available; crop at farm B completely destroyed by diseases.

Maturity of Hybrid Blackeyes.—Early maturity is desirable when Blackeyes are grown for grain. Early maturity is usually antagonistic to yield but the combination of early maturity and yield was secured in a considerable number of hybrids. The maturity of a variety alters with the year, the date of planting, the type of soil and its fertility, and irrigation practice. All the hybrids, if not seriously attacked by diseases, continue to grow and put out new leaves and flowers until killed by frost. On the contrary, the common California Blackeye tends to mature at an early date, especially when attacked by diseases. Most of the hybrid varieties placed with farmers possess the quality of continuous blooming, although the major part of the crop matures at a definite date. Where a further setting of pods continued, there occurred a serious reduction in quality of the seed through discoloration by moisture from dews and rains, and by evaporation from the growing plants. Usually after the seed is sufficiently mature to show clearly the outline of the "eye" the bean will mature

to the point where it will yield a good marketable product. The seed harvested in a more immature condition will usually be blown out in the threshing, or be removed in recleaning before marketing. These reasons make it advisable for the Blackeye farmer to cut his crop as soon as the first full setting is mature.

A measure, to apply generally, of the exact number of days from planting to maturity of the Blackeye cannot be given because of the many factors involved. The earliest maturing variety, Blackeye 8274, was used as the basis for

Fig. 19.—Disease resistant Blackeye hybrid yielding 4,200 pounds per acre as contrasted with 700 pounds per acre for California Blackeye beans in adjacent plot.

comparison. The relative, or comparative, difference in maturity compiled for data from plots in several parts of the state over a period of years is given in table 7.

Comparative Yields of Blackeye Hybrids.—The yield of Blackeye beans per acre in California cannot be given because no authentic records exist of the acreage grown each year. In the Turlock-Modesto area the yields have been estimated at 12 bags per acre under normal conditions. Attack by disease probably reduces this estimate. At the inception of Blackeye culture in this area, 20 bags per acre are given as the high point of production. With the introduction of the new disease-resistant hybrid Blackeyes, 20 bags per acre are commonly secured with exceptional yields of double this quantity (table 8). Test yields in small plots duplicate these records (fig. 19).

Wilt-resistant hybrids derived from crosses between California Blackeye and Virginia Blackeye (a cowpea-wilt-resistant variety) gave rise to a number of hybrids highly resistant to wilt (Kendrick, 1936). Under severe nematode attacks all hybrids succumbed. Some of these wilt-resistant varieties produced good yields where nematodes were not a factor, but the trade objected to the

size, shape, and quality of the beans. Excessive vine growth on many of these hybrids was objectionable. None of these wilt-resistant hybrids has persisted.

Among the hybrid varieties tested, the farmers generally preferred nos. 8145 (California Blackeye 5) and 8140. Variety 8145 is very early and has the upright, small vine of the common California Blackeye and therefore does not disturb the cultural practices usually followed in growing and harvesting Blackeyes. Variety 8140, even though it matures a little later and is more viny, has many of the characters of the common Blackeye. Both varieties are high yielders of good-quality seed. Where cowpea-wilt attack was severe, both varieties suffered with consequent crop losses. Yet both varieties had passed cowpea-wilt-resistant tests in the plots. It is suggested that there may be forms of cowpea wilt to which these varieties are not resistant. Where these varieties were grown without irrigation after planting no especial cowpea-wilt injury occurred. When the new disease-resistant Blackeye varieties appeared, farmers increased the number of irrigations to 3 or more after the beans were up. The usual method consists in retaining a flood of water between borders. This practice favored the attacks of both cowpea wilt and nematodes. Under the furrow method of irrigation the injury to vines did not occur to any measurable extent.

On tests covering several years, some of the hybrid Blackeyes that grew with greater vigor proved to be highly resistant to cowpea wilt and nematodes under the flooding system, whereas other varieties succumbed. All of these varieties mature a few days later than the 8145 and 8140 and their vines are larger and more vigorous, but they produce good crops where the more susceptible hybrids fail. These resistant varieties are being increased for distribution.

DISEASE-RESISTANT BLACKEYE HYBRIDS RELEASED TO FARMERS

After four to six backcross generations of disease-resistant hybrids, sufficient fixity was secured to warrant distribution of seed to farmers (fig. 16). These resistant varieties were not entirely fixed in all characters but were of good marketing quality, superior yield, and were highly disease resistant. Perhaps because of the influence of backcrossing, none of the hybrid varieties were as resistant to the three diseases under test as the resistant Iron parent.

In the advance of disease, the California Blackeye established itself in competition with many other Blackeye varieties. The seed is medium in size with a standard index of 24.0 when soil and cultural conditions are favorable. (The index is the weight in grams of 100 seeds.) Under unfavorable conditions and disease attack, the size index may drop to 18.0 and the seed coat and color deteriorate. For this reason the trade prefers somewhat larger-sized seed which is thought to be produced by fertile soil, good cultivation, and freedom from disease. The size of the seed in the hybrid varieties distributed to farmers is mainly attributable to inheritance.

The size of the California Blackeye vine is small and the shape upright with no marked side spreading (fig. 20). It is one of the earliest of the Blackeye varieties. These qualities that afford easy cultivation and easy, early harvest are favored by the farmers who dislike the larger, more vigorous, new disease-resistant hybrid varieties. Recent breeding operations on the original hybrid

Fig. 20.—Center two rows, California Blackeye beans dead from diseases; disease-resistant hybrids are on both sides. Hilmar, California.

Fig. 21.—California Blackeye no. 7. This variety is resistant to root-knot nematode, cowpea wilt, and charcoal rot.

stocks have produced varieties superior in yield and disease resistance to the earlier distributed hybrids. Some of these are almost as early as the California Blackeye and retain the same erect form of vine. Other varieties, later and more viny and prolific, are more difficult to harvest. Modern bean cutters adapted to all types of tractors, however, remove this difficulty.

Blackeye 20–20 has a coarse seed-coat texture of dull color; the size of its seed is large, with an index of 31.0. The vine is medium in size, and matures medium early, with good yield. Disease resistance is good but not fixed. Objections to the marketing quality caused its rejection.

Fig. 22.—California Blackeye no. 1. Four backcrosses. Common Blackeye bean failed to produce a crop.

Fig. 23.—Blackeye 7711 very resistant to root-knot nematode, cowpea wilt, and charcoal rot. This variety is highest in yield and latest in maturity of the Blackeye × Iron hybrids. No backcross.

Blackeye M 32 has a coarse, but well-wrinkled seed coat, dull yellowish or rusty in color, and medium-sized seed with an index of 26.0. The large, vigorous, upright, medium-maturing vine is highly resistant to cowpea wilt and root-knot nematode. Blackeye M 32 was dropped because of poor seed-coat color.

Blackeye 8130 produces seeds normal in size (index 24.0), with good wrinkles and of bright white color. The vine is medium sized and semierect. It is highly disease resistant.

Blackeye 8135 produces seed above medium in size (index 28.0), with satisfactory wrinkles and color, and of medium early maturity. The vine is red stemmed, large, and flat. The disease resistance is good but the split seed coats and prostrate vine caused it to be rejected.

Blackeye 8137 has a larger than medium seed (index 26.0) with good wrinkles and a bright white color; it has some twisted seed. The vine is medium early, upright and vigorous. It possesses good disease resistance and because of its vigor grows well in a wide range of soils. Rigid selection produced a satisfactory variety which was Calapproved and distributed as California Blackeye 7 (fig. 21).

Blackeye 8140 has a larger than medium seed somewhat more oblong than the California Blackeye; it is variable in shape and size, with satisfactory wrinkling but dull white in color. The vine is flat and wide spreading, yielding well. Under severe cowpea-wilt attack it is badly injured; for this reason it was not certified.

Blackeye 8145 produces a seed somewhat larger than California Blackeye with an index of 26.0. The shape, color, wrinkles, and "eye" are identical with the California Blackeye. The vine has the same upright posture, small size (fig. 15), and early maturity as the Blackeye parent but, in addition, is resistant to cowpea wilt and nematodes. Under certain attacks it succumbs to wilt and nematodes and is also susceptible to charcoal rot. Because of its close resemblance to the California Blackeye, it is popular with the farmers and was certified as California Blackeye 5. It is the most extensively grown variety. Attempts to secure greater disease resistance by selection failed because it is fixed for this character.

Blackeye 8146 has a very large seed (index 32.0) with excellent wrinkles, a bright color, and medium maturity. The vine is large, flat, and vigorous, yielding well. The large seed is inclined to twist; it possesses hollow centers that are likely to crack during threshing.

Blackeye 8147 has a large (index 30.0), well-shaped seed with good wrinkles and color. The leaf color is dark green and the vine medium in size, upright and vigorous. The yields are high and the maturity medium early. Selections have greatly improved its resistance to cowpea wilt and nematodes.

Blackeye 8148 has a large seed (index 31.0) well wrinkled and of good color. The vine is large, vigorous and erect, oval in form. Its disease resistance and yield are high.

Blackeye 8149 has a large seed (index 29.0), but smaller in size than the Blackeye hybrids whose hollow seeds are prone to crack during threshing. The vine is vigorous, oval, upright, and medium early in maturity. Its yield and disease resistance are superior to the varieties described above for the perfected form finally secured by selection (fig. 14).

Blackeye 8152 bears a seed (index 26.0) larger than standard (index 24.0), well wrinkled, and bright white in color. The vine is large, vigorous, upright, medium in maturity, and very disease resistant. It has produced well in northeastern Texas.

California Blackeye 1 possesses a large seed (index 28.0), somewhat oblong, with fine wrinkles and a very bright white color. It is resistant to both cowpea wilt and nematodes and, in addition, is highly resistant to charcoal rot. Resistance to charcoal rot makes this variety suitable for dry-land farming where charcoal rot is likely to occur. The variety is certified (fig. 22).

Chino 2 closely resembles California Blackeye 1 in size, color, and wrinkles of seed, but it differs in the size and behavior of the vine, which matures slightly later than California Blackeye 5 (8145). The vine is more vigorous than California Blackeye 5 and greatly to the improvement of the crop, tends to spread sufficiently to fill spaces left vacant. It also is superior in disease resistance to California Blackeye 5. The improvement was brought about by plant selection of unfixed material.

Blackeye 7711 is a dual-purpose variety—a high yielder of excellent-quality seed. The seed is above medium in size (index 26.0) and somewhat oblong. The vine has all the vigor and size of the Iron-cowpea parent and is superior to all other hybrids in disease resistance. The vigor and disease resistance of the Iron parent are preserved by omitting the backcrossing practiced in the breeding of the other hybrids. As a result of several years of plant selection, it has also outyielded all other hybrids in the final form. Blackeye 7711 (fig. 2) is very drought resistant and has produced consistently on good soil under dry-land farming. It is also a good producer on heavy soils and offers promise on old riceland. The objections lie in its late maturity and in its large vine which offers difficulties in harvesting. Bean cutters designed for attachment to tractors remove this difficulty. The variety is certified but the later improvements have not yet reached certification (fig. 23).

DISEASES OF BLACKEYE BEANS

DISEASES FOUND IN CALIFORNIA[6]

In breeding for resistance to the three principal diseases of Blackeye beans in California, the presence of other diseases that may become important, when the principal ones are subdued, must be considered. A list of the diseases already encountered in California follows (Harter and Zaumeytr, 1944; Anderson, *et al.*, 1926):

Cowpea wilt (*Fusarium oxysporum* f. *tracheiphilum*)
Charcoal rot (*Sclerotium bataticola, Macrophomina phaseoli*)
Stem canker, scab, or sore shin (*Rhizoctonia solani*)
Dry root rot, or fusarium root rot (*Fusarium solani* f. *phaseoli*)
Sclerotinia wilt, or cottony rot (*Sclerotinia sclerotiorum*)
Southern wilt, or southern blight (*Sclerotium Rolfsii*)
Verticillium wilt, or verticilliosis (*Verticillium albo-atrum*)
Cotton root rot (*Phymatotrichum omnivorum*)
Black root rot (*Thielaviopsis basicola*)
Powdery mildew (*Erysiphe polygoni*)
Rust (*Uromyces vignae*)
Pythium spp.
Curly top (a virus disease of sugar beets and other crops caused by *Eutettix tenellus*)
Root-knot nematode (*Heterodera marioni*)
Aphid spot (caused by the lygus bug)
Crumple leaf (a physiological disease—effect of low temperature)

[6] For the identification of certain of these diseases, the author is especially indebted to W. C. Snyder and J. B. Kendrick of the Division of Plant Pathology.

Cowpea wilt, caused by *Fusarium oxysporum* f. *tracheiphilum,* is confined to cowpeas. It is carried by diseased straw or upon the surface of beans, but is not borne internally in the seed. It lives over in the soil where it attacks the Blackeye seedling. The early attacks show in the wilted seedling, but later the lower stem and root become swollen with blackened inner bark which extends well up the plant. Resistant varieties comprise the only means of control. A number of these are available.

Charcoal rot, caused by *Sclerotium bataticola* (*Macrophomina phaseoli*), attacks a considerable number of crops and occurs in practically all areas of the state. High temperatures and unirrigated land favor the fungus, but irrigation and subsequent evaporation reduce the temperature and the disease. The disease manifests itself when the plant approaches maturity. Diseased plants show small black sclerotia imbedded in the bark of the stems and roots. Disease-resistant varieties offer the only economic solution (Andrus, 1938). One of those varieties resistant to charcoal rot is California Blackeye 1 (Young, 1937; Tompkins and Gardner, 1935).

Stem canker, scab, or sore shin, caused by *Rhizoctonia solani,* is present in all arable soils. This fungus is favored by cool weather and abundant moisture. Early plantings may be entirely destroyed by unfavorable weather. Seed planted early should always be dusted with Spergon, Semesan, or some other effective treatment. Spergon is favored because it is only slightly toxic to nodule bacteria. Excessive irrigation may continue the attacks until the plant matures. The disease is detected by the rusty or brick-red color of the diseased bark of the roots and the swollen, thickened skin. Seedlings dying from scab drip when squeezed, in contrast with dry rot which does not drip.

Dry root rot, or fusarium root rot, is caused by *Fusarium solani* f. *phaseoli.* This disease is found in all Blackeye areas (Weimer and Harter, 1926) but causes minor injury in the interior valleys. A reddish or rusty color is noted on the root bark and interior of the stem of attacked plants. The greatest injury appears in the seedling stage but the injuries may continue until the crop matures. Seed treatment with Spergon is beneficial for early planting. No resistant varieties are available.

Sclerotinia wilt, or cottony rot, caused by *Sclerotinia sclerotiorum,* attacks vines close to the surface of the soil, usually girdling the root in a pattern that resembles mouse damage. White fungus mycelium is usually present at the soil surface, but in the soft central pith of the stem large black sclerotia are often found. No resistant varieties are available. By ridging the row of vines to keep water away from the root crown, or by providing a dry surface soil, this disease can usually be prevented.

Southern wilt, or southern blight, is caused by *Sclerotium Rolfsii.* This disease is mainly spread by sugar beets but attacks many other crops. Crop rotation and the use of nitrogenous fertilizers reduce the attacks (Leach and Davey, 1934). The presence of black sclerotia serves to identify the disease.

Verticillium wilt, or verticilliosis, caused by *Verticillium albo-atrum,* affects a number of crops, including cotton and tomatoes (Baker, Snyder, and Hansen, 1940). The vines show a yellowing of the leaves and give poor yields. Verticillium wilt is usually not a serious disease on Blackeyes. No remedy is known; only resistant varieties escape the disease.

Cotton root rot is caused by *Phymatotrichum omnivorum*. This disease, found attacking cotton and many other crops in Texas, New Mexico, and Arizona, is apparently indigenous to these regions. It has been identified in isolated areas in southern California. The fungus destroys the smaller rootlets and invades the vascular system, causing wilt and death of the plant. An oil-spot spread follows initial infestation. As it is carried in the soil by the sclerotia, crop rotation with resistant crops is indicated. If cotton root rot is suspected, the nearest agricultural commissioner should be notified.

Black root rot, caused by *Thielaviopsis basicola,* attacks Blackeyes and is identified by a blackening of the stem. It attacks other crops also. At present the damage to Blackeyes is restricted.

Powdery mildew, caused by *Erysiphe polygoni,* is usually most severe in coastal fields under the influence of summer fogs, but it may also occur in the interior valley late in the season if too much water has caused excessive growth and, as a consequence, excessive shade. A bluing of the stems and leaf ribs, usually accompanied by characteristic powdery leaf surface, indicates mildew. Sulfur dusted on the afflicted plant in the forenoon, before winds occur, ordinarily stops the mildew.

Rust, caused by *Uromyces vignae,* infrequently appears on the leaves of Blackeyes in fields in the southern part of the state but not elsewhere. The crop damage is slight.

Pythium wilt, caused by *Pythium* spp., is severe when too much water is applied to the crop causing a drop in temperature; otherwise the wilt causes little damage.

Curly top, a virus disease carried by the beet leafhopper, *Eutettix tenellus,* attacks a number of crops including Blackeye beans (Severin and Henderson, 1928) and common beans. Blackeye fields in the San Joaquin Valley have been ruined by curly top, a disease recognizable by a peculiar down cupping and curling of the leaves. The flight of the beet leafhopper has been seen confined, by a canal, to one side of a field; in this area the crop was badly damaged, whereas the rest of the field remained normal. No remedy is suggested because curly top in Blackeyes occurs very irregularly.

Aphid spot is a term given to the yellowish disfiguring spots sometimes found on the seed coats of the Blackeye. The disfigurement adversely affects the sale of the beans. No damage from aphids has been indicated. The yeast spot, caused by the fungus *Nematospora phaseoli* (Wingard, 1922*a*, 1922*b*), has not been identified in California. Recently, it has been demonstrated that the attacks by lygus bugs (Baker and Snyder, 1945) are the cause of aphid spot. The new insecticide DDT has proved economically effective against lygus bugs. Some of the hybrid Blackeyes also seem to be resistant.

Crumple leaf is caused by temperatures lower than those normally required for healthy vigor, such as cold spring weather in the interior valleys and in all coastal valleys subject to cool summer temperatures because of the fogs. This leaf trouble may be confused with curly top which, when contrasted with the irregular crumpling from cold, differs decidedly in cupping effect. In the interior, with the change from cold temperatures to normal heat, crumple leaf disappears. In the coastal valleys, it persists and definitely reduces the yield and quality of Blackeyes.

Root knot, caused by the nematode *Heterodera marioni*, is undoubtedly the worst disease of Blackeyes. It is widespread and thrives in sandy soils usually preferred by the Blackeye (U. S. Agricultural Research Administration, 1943). Nematodes attack in irrigated soils, but seldom enter dry soils not subject to irrigation. In the San Joaquin Valley, where Blackeye beans follow uprooted peach, fig, walnut, or almond orchards, or vineyards, nematodes invariably occur. As the root-knot nematode occurs in more than 2 million acres of perhaps the best soils of the state, it may be considered a menace to Blackeyes planted in irrigated soil. Chemicals applied to the soil have proved to be very expensive and of temporary benefit only. The one effective remedy to root-knot nematode lies in the use of resistant Blackeye varieties. A number of these varieties are now being grown in all the Blackeye areas.

DISEASES NOT OCCURRING IN CALIFORNIA

The following list includes diseases attacking cowpeas in other states, but not in California (Harter and Zaumeyer, 1944; Anderson *et al.*, 1926):

Pod and leaf blight (*Cladosporium vignae*)
Leaf spots (*Cercospora vignae, C. cruenta, C. dolichii, Ameriosporium occonomicum*)
Anthracnose (*Colletotrichum lindemuthianum*)
Phytophthora, or downy mildew (*Phytophthora phaseoli*)
Yeast spot (*Nematospora phaseoli*)
Bacterial canker spot (*Bacterium vignae*)
Bacterial blight (*Bacterium phaseoli*)
Cowpea mosaic (cucumber mosaic)

Pod and leaf blight, caused by *Cladosporium vignae*, occurs in eastern states but seldom in California, except in coastal areas subject to summer fogs (Gardner, 1925).

Leaf spots, caused by *Cercospora vignae, C. cruenta, C. dolichii, Amerosporium occonomicum*, are not likely to occur except under unusually moist conditions.

Anthracnose, caused by *Colletotrichum lindemuthianum*, appears as blotches or sunken spots on pods and leaves. The disease occurs only under rainy conditions or sprinkling which simulates rain. It is not likely to be found in California.

Phytophthora wilt, or downy mildew, is caused by *Phytophthora phaseoli*. This disease causes considerable injury when overirrigation is practiced.

Yeast spot, caused by a fungus *Nematospora phaseoli*, has not been found in California and is not likely to occur except under rainy conditions (Wingard, 1922*a*, 1922*b*).

Bacterial blight, caused by *Bacterium phaseoli*, and bacterial canker spot, caused by *B. vignae* (Hoffmaster, 1944), probably will not occur except under unusually rainy conditions, which are not found in California in summer (Burkhalter, 1944).

Cowpea mosaic, which occurs in the southern and eastern states, has not been found in California. As it is not seed-borne, it cannot be brought in by seed. Cucumber mosaic, spread by insect vectors, appears responsible for the disease. Most cowpea varieties are susceptible (Chester, 1939; Briant and Martyn, 1929).

INSECTS AND OTHER PESTS CAUSING ECONOMIC DAMAGE

Although many insects attack Blackeyes, relatively few cause much damage. These insects are listed with the standard control measures. When other insects appear, the entomologists of the California Agricultural Experiment Station should be consulted (Essig and Hoskins, 1934).

The red spider (*Tetranychus althaea*) and similar mites sometimes attack Blackeyes but not to the same extent as they attack common beans. As soon as the infestation appears, sulfur dust should be used in a combination of 90 parts of fine dry sulfur to 10 parts of finely ground dry lime. If the area is small and isolated, the sulfur should be used for a considerable depth adjacent and should be repeated in about 2 weeks.

Bean thrips (*Hercothrips fasciatus*), apparently a native of the state, may be expected in any area since it survives on a number of weed hosts (Bailey, 1937). By eliminating prickly lettuce (*Lactuca scariola*) and sow thistle (*Sonchus oleraceus*) the worst hosts of the bean thrips are removed. Blackeyes are fairly resistant to bean thrips, especially when the fields are well irrigated and the Blackeye plants kept in a healthy growing condition. Thrips do not propagate in sandy soils as freely as in heavy soils that crack and permit the larvae to penetrate, where they pupate and later emerge to attack the Blackeyes. The presence of thrips can be detected by the numerous black, shiny spots of excrement. When these insects attack in large numbers, they should be sprayed with a highly refined commercial oil emulsion at 2 per cent concentration, to which has been added ½ pint of nicotine sulfate (40 per cent) in 100 gallons of emulsion (Bailey, 1937).

The lima bean pod borer (*Etiella zinckenella*) prefers lima beans but is known to attack Blackeyes. The small gray moth lays its eggs on the green pod. There is no known practical control.

The sugar-beet wireworm (*Limonius californicus*) attacks early-planted Blackeyes, but after the soil becomes warm the wireworms usually drop below the planting level of the seedling beans. No remedy is known (Stone, 1941).

Corn earworm (*Heliothis armigera*) may attack limas and Blackeyes but usually in such small numbers that the attack is of little economic importance.

The cowpea weevil (*Acanthoscelides obtectus*) causes considerable damage to Blackeyes; not only does it lay its eggs on the bean pods and beans in the field as soon as they mature, but it also continues to lay eggs and infest Blackeyes in the warehouse where it continues, generation after generation (Larson and Fisher, 1938). The most effective method of control lies in harvesting and threshing the Blackeyes as soon as they are ripe; this should be followed promptly by fumigation at the warehouse or wherever they are stored. Carbon disulfide is commonly used. The fumigation chamber should be tight, with the temperature 65° F or more. From 10 to 20 pounds of carbon disulfide should be used for every 1,000 cubic feet of space, depending upon how tight the chamber is and how well filled it is with beans. A minimum exposure of 24 hours, and usually an exposure of 48 hours, is required. Carbon disulfide gas is heavier than air, with a boiling point at 115° F; its high degree of inflammability necessitates great care in keeping lighted lanterns, pipes, cigarettes, and cigars away from chambers being fumigated.

Methyl bromide (Linsley and Michelbacher, 1943) is a very effective fumigant without the inflammable qualities of carbon disulfide. It is dangerous to human beings if the fumes are breathed into the lungs, however, but it is not harmful to food products. It has a boiling point of 40° F but is most effective above 60° F. It should be used only by experienced persons. The minimum dosage per 1,000 cubic feet is 1 pound. It is slow acting but very effective against both insects and their eggs.

Chloropicrin (tear gas) is very effective, evaporates slowly, but is a poisonous gas that should be used only by experienced persons. It should be used at a temperature not less than 70° F. Many reports of injury to seed germination have been received and, for this reason, it is not recommended for Blackeyes to be used for seed.

Sources of cowpea-weevil infestation should be removed early to prevent continuing generations of weevils. Unharvested Blackeyes, stack bottoms where beans are threshed or recleaned, refuse dumps about warehouses or buildings or exposed, unfumigated stores of seed, all contribute to the spread of weevil infestation and should be eliminated as promptly as possible. In this way a great part of the field infestation can be prevented. In some counties, local ordinances enforce the destruction of all Blackeye straw and refuse by April 15 to prevent weevil spread (Larson and Fisher, 1938).

The Angoumois grain moth (*Sitotroga cerealella*), common in all grain, also attacks stored Blackeyes. It is controlled by the same fumigation methods used to control the cowpea weevil.

Bean aphid (*Aphis rumicis*) may collect in spots, damaging the tender plant tips. Dusting with 5 per cent nicotine or using nicotine and casein spray will check them.

Root-knot nematodes (*Heterodera marioni*) are very destructive to Blackeyes. Sandy soils in which Blackeyes are usually grown also favor nematodes, whereas heavy soils retard them. In many areas the root-knot nematode has long been established in peach, walnut, and fig orchards, in vineyards, and in alfalfa and cotton fields where these crops are injured but do not die. Blackeyes following them may be injured or destroyed. Root-knot nematode is not controlled by long flooding and is only temporarily controlled by chemicals at prohibitive expense (Brown, 1933). The only practical remedy lies in breeding for resistant varieties (Tyler, 1944). This has been done and is discussed under "Breeding for Disease Resistance in Blackeyes."

PRICE, PRODUCTION, AND MARKETING OF BLACKEYE BEANS

The price and production of Blackeye beans from 1909 to 1943 are given in table 9. Under normal conditions, the price of Blackeyes varies inversely with production; that is, when production is low the price is high and vice versa. Exceptional variations were caused by war, such as the demand for beans created by World War I; the boom in prices that followed lasted until the depression, beginning in 1929. Prices of Blackeyes were high during that time, with slight exceptions in 1921, 1922, 1926, and 1927 (fig. 24). The price since has varied according to supply and demand until the effect of World War II influenced the markets. This condition was stabilized by the fixing of prices for

TABLE 9

PRODUCTION AND PRICE OF BLACKEYES IN CALIFORNIA, 1909 THROUGH 1943*

Year	Field-run yield†	Price
	100-pound bags	*dollars*
1909	80,000	4.65
1910	100,000	5.85
1911	225,000	3.80
1912	204,000	3.30
1913	80,000	5.50
1914	150,000	5.25
1915	405,000	3.75
1916	275,000	6.80
1917	300,000	8.20
1918	463,000	4.80
1919	200,000	7.20
1920	180,000	6.45
1921	400,000	4.55
1922	300,000	4.76
1923	275,000	6.76
1924	250,000	9.64
1925	400,000	5.72
1926	460,000	3.89
1927	300,000	4.93
1928	428,000	9.47
1929	514,000	8.36
1930	852,000	3.33
1931	459,000	2.58
1932	275,000	3.35
1933	587,000	2.92
1934	525,000	4.04
1935	615,000	4.55
1936	705,000	4.99
1937	857,000	2.91
1938	512,000	3.87
1939	573,000	4.56
1940	1,154,000	2.76
1941	704,000	5.02
1942	733,000	5.80
1943	896,000	5.80

* Data from:

Wellman, H. R., and E. W. Braun. Beans (series on California crops and prices). California Agr. Exp. Sta. Bul. **444**:18, 61. 1927.

United States Department of Agriculture. Agriculture Statistics **1940**:302. 1940; **1944**: 275. 1944.

Pacific Rural Press, annual issues.

† Yields quoted in field run. Recleaning reduces the total as follows: 1934 through 1938, five-year-average field run was 655,000 one hundred-pound bags: recleaned was 612,000. Percentage reduction was 6.5.

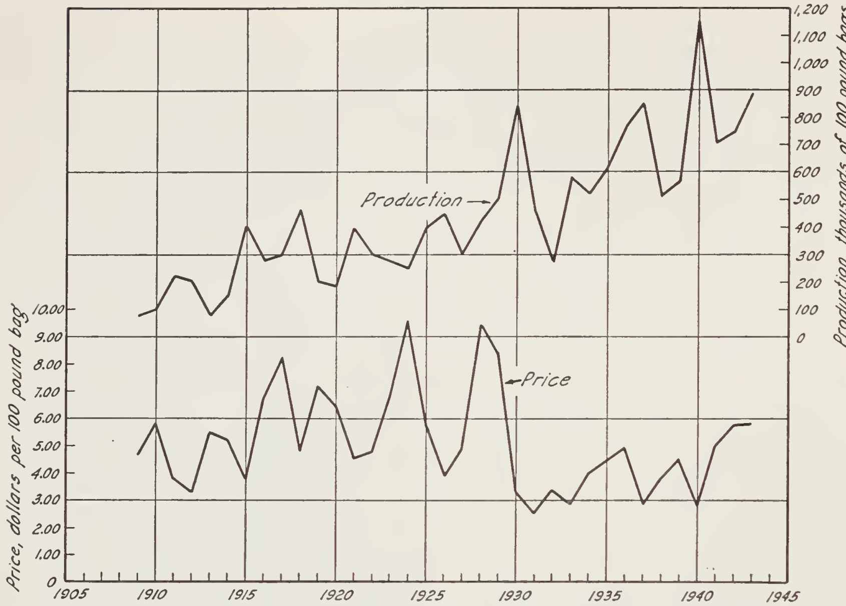

Fig. 24.—Production and price of Blackeye beans in California, 1909 through 1943.

TABLE 10

Proportion of Blackeye Beans to Total Bean Production in California, 1931 through 1943*

Year	Blackeye beans	Total beans	Proportion of Blackeyes to total
	100-pound bags	*100-pound bags*	*per cent*
1931	459,000	3,467,000	13.2
1932	275,000	2,484,000	11.1
1933	587,000	3,520,000	16.7
1934	525,000	3,684,000	14.3
1935	615,000	3,966,000	15.5
1936	765,000	4,081,000	18.7
1937	857,000	5,369,000	16.0
1938	512,000	4,501,000	11.2
1939	573,000	3,991,000	14.3
1940	1,154,000	5,490,000	21.0
1941	704,000	5,139,000	13.7
1942	740,000	4,894,000	15.1
1943	890,000	5,169,000	17.2
Average 1931–1943	....	....	15.2

* [Clarke, L. M.] Bean production by varieties for California and other leading states. p. 2. California Crop and Livestock Rept. Serv. 1944. (Mimeo.)

Blackeyes, U. S. no. 1 grade, in 100-pound bags by the O. P. A. (Office of Price Administration) at $5.80 in 1944 and $6.20 in 1945.

MARKETING BLACKEYE BEANS

Blackeyes grown in California are marketed almost entirely in the southern states where their value as food is appreciated because of long acquaintance with the crop. The high quality of the California-grown crop is attributable to

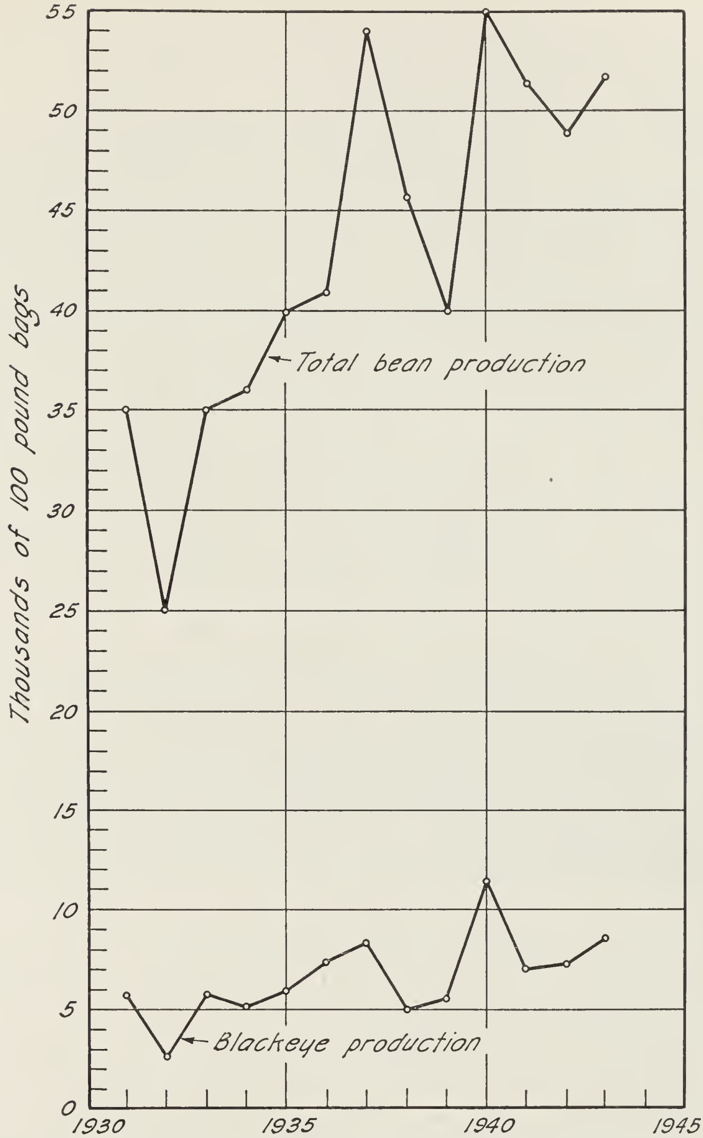

Fig. 25.—Production of Blackeye beans to total bean production in California, 1931 through 1943.

the rainless summers that are not encountered in the southern states. The climatic conditions likewise favor the use of labor-saving machinery in cultural and harvesting operations.

The extent of Blackeye culture in California is definitely limited by the restricted marketing area so that the price and production follow each other closely in an inverse ratio. This relation does not necessarily hold true for other beans, such as the Pink, Pinto, and Red Kidney, which are grown in other states and have a wider market. The ratio of the Blackeye crop to the total bean crop

of the state follows within fairly close limits. In other words, the conditions that increase or decrease the production of the bean crop of the state equally affects the Blackeye production (fig. 25).

Some Blackeyes formerly were imported from Mexico but this source has been shut off by the removal of American farmers from Mexico.

Table 10 shows the proportion of Blackeyes to total bean production in California. The acreage of Blackeyes is not affected by the changes in the price of other beans because the areas where Blackeyes are principally grown are not well adapted to other beans. Over a thirteen-year period (1931 through 1943) Blackeyes comprised about 15 per cent of all the dry beans produced in the state. This proportion has gradually increased from 3.5 per cent in 1910 to 9.0

TABLE 11

Market-Grade Requirements for Blackeye Beans

Grade*	Maximum limits of defects consisting of sound splits, damaged beans, contrasting classes, and foreign material				
	Total defects†	Contrasting classes	Foreign material	Stones	Other classes that blend‡
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
U. S. no. 1	2.0	0.5	0.5	0.2	5
U. S. no. 2	4.0	1.0	1.0	0.4	10
U. S. no. 3	6.0	2.0	1.5	0.6	15

* The following are further market-grade classifications: "*U. S. Substandard* shall include beans of any of these classes which do not come within the requirements of the specifications for the grades U. S. no. 1, U. S. no. 2, or U. S. no. 3, or for the grade U. S. Sample Grade."

"*U. S. Sample Grade* shall include beans of any of these classes which are musty, or sour, or heating, or hot, or weevily, or materially weathered, or which are otherwise of distinctly low quality."

† "The beans in the grade U. S. no. 2 of the class Blackeye may contain not more than 0.2 per cent, and the beans in grade U. S. no. 3 of this class may contain not more than 0.5 per cent of clean-cut weevil-bored beans."

‡ "The beans in grade U. S. no. 1, U. S. no. 2, and U. S. no. 3 of any of these classes shall be well-screened hand-picked beans. Definition—hand-picked beans shall be beans of any class except Pinto, lima, baby lima, and mixed beans, which meet the grade requirements of any of the grades U. S. no. 1, U. S. no. 2, or U. S. no. 3, which have been hand-picked or otherwise processed so that they contain not more than 0.3 per cent badly damaged beans, nor more than 0.01 per cent contrasting classes, and not more than 0.01 per cent foreign material, and which do not contain any stones."

per cent in 1918, 13.5 per cent in 1926, to a final average of 15.2 per cent. The proportion of Blackeyes tends to increase at the expense of other beans, especially in hot areas in the San Joaquin and Sacramento valleys where land under irrigation is being increased (fig. 25).

No coöperative marketing organization exists at present for Blackeyes as it does for lima beans, but "pools" of Blackeyes are formed for sale of the crop in connection with the California Lima Bean Growers Association. This plan facilitates shipping mixed carload lots to the eastern markets. Otherwise the crop is marketed by well-established firms familiar with the California crop.

MARKET GRADES

The United States Department of Agriculture under the Agricultural Marketing Service has established market grades of beans, including Blackeyes (U. S. Dept. Agr. War Food Administration, 1944). The requirements are:

Blackeyes may not contain more than 2 per cent of beans of contrasting classes and not more than 15 per cent of other classes that blend (table 11). When greater amounts are included the beans are classed as "mixed" and graded under this classification.

USES OF BLACKEYE BEANS

BLACKEYES AS SNAP BEANS AND SPROUTS

In the southern states, cowpeas (Blackeyes) are grown everywhere as a garden crop for their green pods and green beans which are harvested and consumed as snap beans. If the pods become too tough or stringy the green or immature beans are shelled out and cooked with the snap pods. Because of the high vitamin content (Reid, 1942), especially B_1, green cowpeas are valuable in the diet during hot weather.

Although Blackeyes have been grown in California for many years, the use of green Blackeyes as a vegetable has only begun. Recently, green Blackeye pods, or snaps, have begun to appear in the Los Angeles, Fresno, and San Francisco markets, where they are in demand by consumers from the southern states. The season may be extended by early and late plantings in thermal areas similar to the Coachella Valley. When the merits of this vegetable are known, the demand should steadily increase.

TABLE 12

Nutritional Analysis of Lima, Pink, and Blackeye Beans

Varieites	Water	Ash	Protein	Fat	Fiber	N-free extract*
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Lima	11.82	4.11	19.25	1.86	5.26	57.70
Pink	9.28	4.31	21.00	3.65	3.29	58.47
Blackeye	9.02	3.56	18.90	1.50	3.12	63.82

* N-free extract includes starches and sugars.

Sprouts from Blackeyes contain a high amount of vitamin C and fair amounts of B vitamins. Twenty-four hours after germination, the sprouts are ready for cooking.

COOKING OF BLACKEYE BEANS

Although California produces the greater part of the Blackeyes marketed for human consumption, relatively small quantities are consumed in the state. This condition is not traceable to the quality and nutritive values of the Blackeye but to the flavor which is as specific to it as the lima flavor is to the lima bean. The analysis of the nutritional qualities is given in table 12.

The Blackeye bean is lower in indigestible ash and fiber and higher in starches and sugars (N-free extract) than the lima and Pink beans. It is also easier to cook. Like other beans the Blackeye is low in fat and is much improved when cooked with fat meat such as pork. The following methods of cooking put forth by the United States Department of Agriculture (Morse, 1920*b*) will be found useful.

Blackeyes Parboiled.—Soak in lukewarm water for several hours, or overnight, and simmer slowly at low heat until tender. Do not use soda in the water. Soaking and slow cooking will make the Blackeyes sufficiently tender. Season well. Pork fat, cheese, onion, green pepper, celery, or tomato combine well as seasoning (Windsor, 1918).

Blackeyes Baked.—After the Blackeyes are cooked tender, the beans can then be baked or fried. To bake cowpeas add to 1 quart of parboiled Blackeyes ¼ pound of salt pork, ½ teaspoon of mustard, ⅓ cup of molasses (preferably sorghum), salt, and a pinch of cayenne pepper. Cover with water and bake several hours.

OTHER USES FOR BLACKEYE BEANS

Blackeye beans were repeatedly reported to have been used for the making of gunpowder in World War I, as well as in World War II. A careful survey of the principal munition plants of the United States definitely disposes of this myth. The Blackeye bean is not used for gunpowder.

Under war conditions and depressions Blackeyes have been roasted and used as a substitute for coffee (Robbins, 1917, p. 460–62).

DISCUSSION AND SUMMARY

The Blackeye is a cowpea of African origin with definite adaptation and edible qualities but more closely resembling the bean than any other legume. In applying the tariff, the Blackeye is classed as a bean. After becoming well established in the southern states, it spread to California where it was found well suited to the warmer irrigated areas and, to a lesser extent, to dry-farmed areas. Climatic conditions that restrict common beans and lima beans, do not apply equally to Blackeyes. Large areas in the San Joaquin and Sacramento valleys and in similar regions are well adapted to Blackeyes.

Cultural methods of soil preparation, irrigation, cultivation, and harvesting are similar to those of other bean crops. Crop rotations with Blackeyes are more widespread and satisfactory than with other beans. Nodulation in Blackeyes is easily established and becomes permanent, although requiring a different culture from beans.

The market for Blackeyes is confined almost exclusively to the southern states, with consequent restrictions on production and price. Because of rainless summers, however, California almost exclusively holds the market for Blackeyes.

Fungus and bacterial diseases and nematode and insect pests attack the Blackeye, but most of these attacks have been met by creating disease-resistant varieties, or by improving cultural practices under favorable weather conditions.

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